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THE RAPID TANNING OF LEATHER BY ELECTRICITY.

WORMS & BALE'S PROCESS.

NOTHING could better prove the gradual progress of the applications of electricity than an examination of some of its new adaptations to industries which, up to recent years, had not, in anything whatever, departed from their primitive methods.

We shall not speak of electric lighting, the development of which is incessant, and the most extensive applications of which no longer surprise us, so thoroughly have they entered into our habits.

From the standpoint of mechanics, electricity keeps its promises. A few years hence, engineers will hardly know the dangerous and cumbersome gas and steam pipes in their shops. Invisible electric conductors will do the whole business, without noise, without leakages, without disengagement of heat and without accident. The machine tool, having become autonomous, through the combination of its electric motor located in the frame, will escape the incessant inconveniences of solidarity that are created by the general

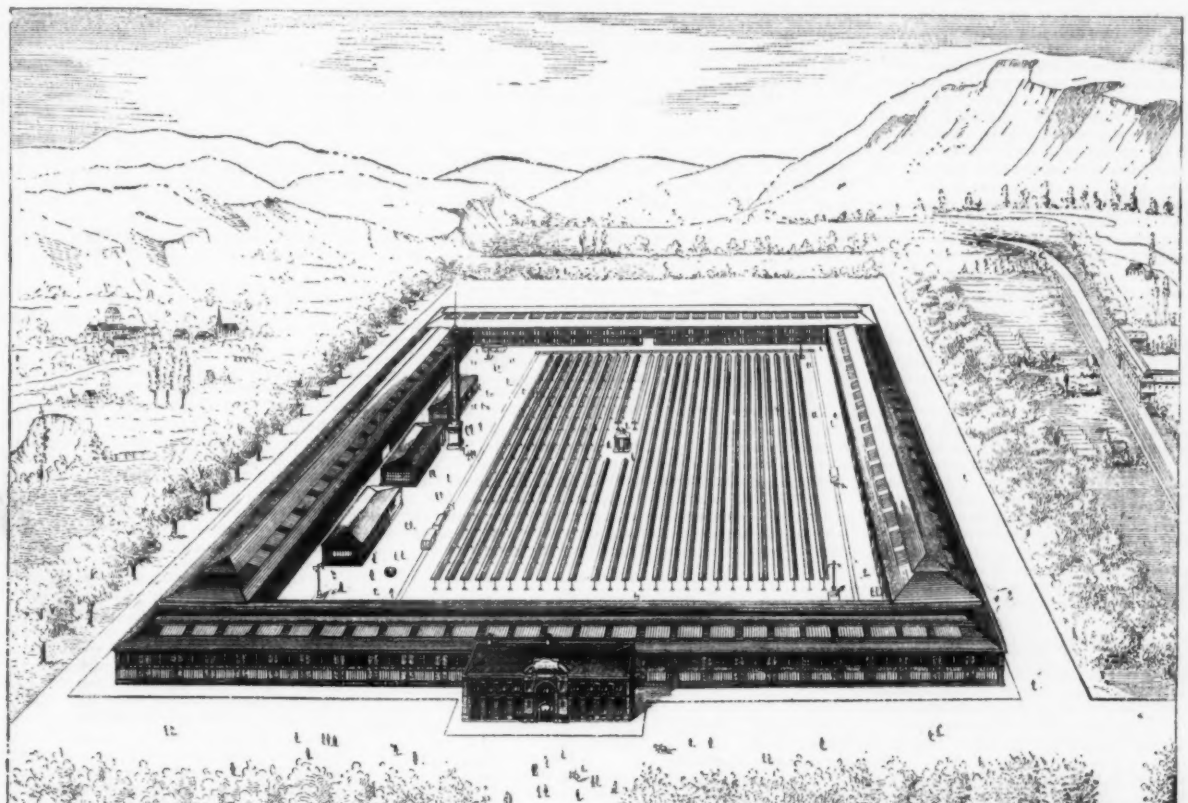


FIG. 2.—BIRD'S EYE VIEW OF A SOUTH AMERICAN ESTABLISHMENT FOR THE ELECTRICAL TANNING OF LEATHER

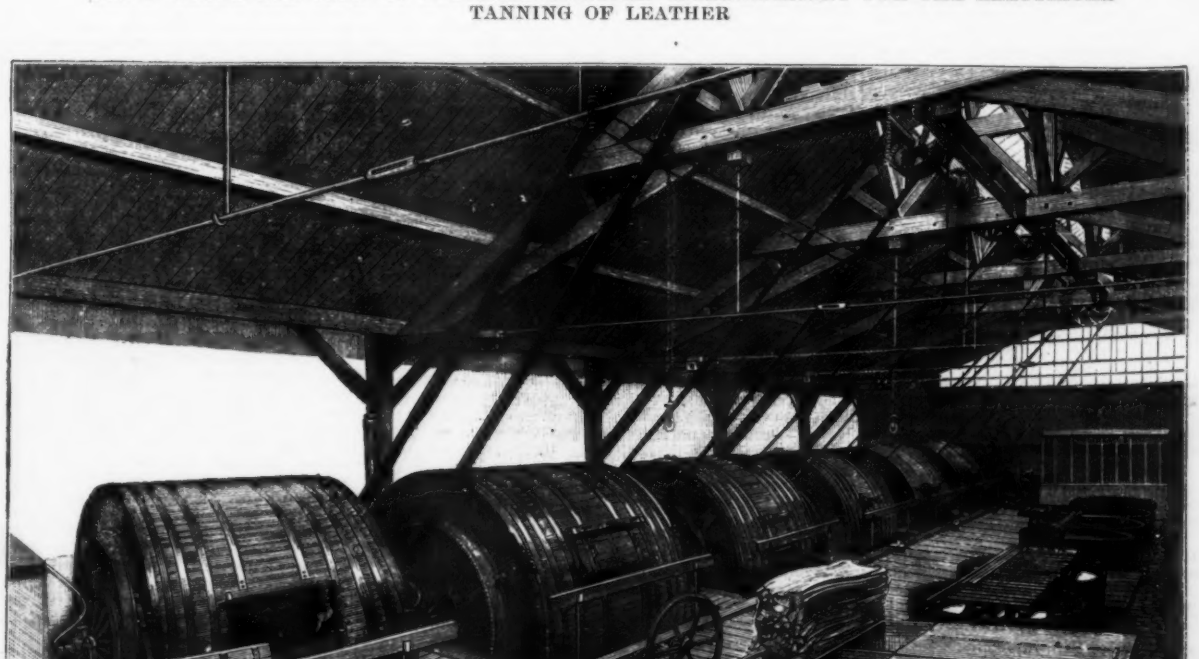


FIG. 1.—GENERAL VIEW OF THE INTERIOR OF MESSRS. BRION & DUPRE'S ESTABLISHMENT FOR TANNING LEATHER BY ELECTRICITY.

transmissions in work shops. From this point of view, it is simplification and economy.

Metallurgy is making, and will make, important electrical conquests. Thanks to electrolysis, we already have aluminum and a whole series of other metals that permit of forming useful alloys. Electric welding will render great services in many cases.

But it is especially in the large chemical industries that great progress has been effected by electricity. Thanks to its property of furnishing oxygen in the active form of ozone in a series of electrolytic actions, electricity has become a common agent of transformation and bleaching for a host of diverse materials. We have already spoken of the processes of bleaching due to Mr. Hermite, which are rendering the greatest service for the bleaching of fabrics and of fibers of all kinds, and of which the whitening and purification of feculæ is one of the most recent applications.

Messrs. Worms & Balé, after long researches, have, in an analogous order of ideas, succeeded in the tanning of leather by electricity. We briefly desribed the process at its inception, while making such reserves as were compatible with an innovation. It now seems that it must come to the front through the results that it has given, and it merits a description in detail.

The hide and leather industry is an extensive one, and gives rise annually to a business figure varying from $93,000,000 to $114,000,000. It occupies the third rank in the French general tabulation of commerce in importation and exportation.

The tanning of hides, which is the base of it, has for a long time been localized between two schools. One of these, the older, finds its principle expressed by a traditional play upon words: It operates 'avec du tan et du temps," that is to say, by a long stay, in the pit, of the hide put in intimate contact with oak bark. The other, called the school of "liquor tanning," shortens, by two-thirds, the time required by the old method. In consists in methodically soaking the hides in a series of vats designated under the name of "train of ooze," containing tan liquors at various degrees of concentration.

Tanning by electricity realizes a much greater progress still, and seems as if it must revolutionize this industry. It permits of tanning *in ninety-six hours* a large ox hide, which in pit tanning requires *sixteen or eighteen months*, and in liquor tanning *five or six months*. This process does away with continuous hand labor and annuls the bad odor characteristic of tanneries.

In electrical tanning, it is always the tannin that transforms the hide into the chemical combination called leather, but electricity accelerates the absorption.

Numerous experiments in this direction have been made and discussed since the origin with an infinitude of doubt and skepticism. Mr. De Meritens is one of the leaders in it, and it appears that his system has been practically utilized for quite a long time in a large tannery at St. Petersburg. But, according to Mr. Charles Poulain, the competent reporter of the jury of class 47 at the Universal Exposition of 1889, no system can be compared, as regards rapidity and perfection, to that of Messrs. Worms & Balé, who, in a few days, tan hides that require from thirty-five to sixty days, even with the other electrical processes known.

DESCRIPTION OF THE WORMS & BALÉ PROCESS.

The principle of the Worms & Balé process is based upon the use of electricity combined with that of rotary drums which put the hides in direct contact with the tanning liquor. Through this combined action of electricity and rotation, an extremely rapid tanning is effected.

The delicate point is the adaptation of the proper organs to the revolving cylinders to obtain a regular continuous passage of the current. To this effect, Messrs. Worms & Balé fix upon the periphery of the revolving drum two metallic hoops that communicate with circular conductors placed in the interior of the cylinder. These conductors receive the current through two elastic rubbers bearing constantly against the two hoops of the drum, and connected with the two poles of a generator of electricity.

There are introduced into the revolving drum:

1. 125 gallons of filtered water per 220 lb. of shaved hides.
2. 2·2 lb. of tannic extract (at 20° B.) per 2·2 lb. of hides.
3. The number of hides to be tanned.

The door of the drum is then hermetically closed, and the latter is set in motion. As soon as the apparatus begins to revolve, the current of electricity is made to pass and the drum is allowed to revolve for the following periods of time:

Ox, cow and bull hides	96 hours.
Hides of horses, heifers and heavy calves	72 "
Skins of calves of medium and light weight	48 "

The operation is performed without odor and almost noiselessly, and with a precision of regularity that strikes one when he visits the fine model tannery of Messrs. Brion & Dupré. It is an absolutely rational and scientific method of manufacture.

After the lapse of time that we have just indicated for the different categories of hides, the tanning is finished and complete. The hides may be utilized for all purposes—patent leather, soft leather, soles, harness leather, etc.

As soon as the apparatus is stopped and the tanning finished, the liquor is run off. An hour afterward, the hides are removed and hung out on poles in order to allow them to dry for a few hours only, at the end of which they may be delivered to the carrier.

THEORY OF THE PROCESS.

As appears from the brief description that we have just given of it, Messrs. Worms & Balé's rapid process of tanning owes its result to electric action along with the rotary motion of the drums in which the hides and the tanning liquor are in incessantly renewed contact.

Prof. A. Rigaud, of the chemical laboratory of the Faculty of Sciences of Paris, has undertaken to make out the theory of the process, and we cannot do better than to give a summary of it.

What is the role of electricity in rapid tanning? This is a delicate point. Mechanical agitation alone is inadequate, even with the addition of a little spirit of turpentine, designed to eliminate the fatty matters incompletely removed in the preliminary operations. Electricity, then, is really the efficacious agent of acceleration. Does it act through the product engendered by electrolysis, notably through ozone? This is what it is well to endeavor to find out. Let us see what takes place in ordinary tanning. The hide, a porous cellular membrane, needs to be inflated in order to absorb the tanning solutions. It is a colloid body which allows solutions to diffuse so much the more quickly in proportion as its pores are more distended. The inflation, in ordinary tanning, is effected through immersion in acid liquid or in a pit containing bran or flour. The formation of the gases resulting from the fermentation of the hides, favored by the medium, distends the pores of the cells and permits of the inflation.

In the electric process, the hide constitutes, after a manner, the electrodes upon which the gases are disengaged—porous electrodes, capable of absorbing the gases resulting from electrolysis. There is observed in the operation but an insignificant disengagement, and this explains the absence of odor. Hides, as has been said by Silvanus Thompson, behave like the plates of accumulators.

In order to get an understanding of the mechanism of the rapid assimilation of the tannin by the hide, it is well to remark that in electrolysis there is a pressure exerted upon the liquid from the negative to the positive pole, and which is necessary for the mechanical carriage of the elements of the electrolyte. Such pressure is shown when a solution is decomposed electrically in a vessel separated into two parts by a porous partition. The level of the water gradually rises, in fact, on the anode side. This phenomenon is utilized notably in the recent processes of the diffusion of molasses.

Mr. A. Rigaud supposes that this osmotic pressure, effecting the carriage of the liquids, obliges the tannic solution to filter through the hide, which constitutes the porous diaphragm. The tannin combines with the gelatine of the hide, and that so much the better when we operate with the action of electricity, which, like heat and light, is a powerful agent of oxidation. Aside from such intervention, moreover, which is likely a form of molecular vibratory action, the quickness of the passage being increased, the quantity of tannin combined in a given time should be larger than when the hide is simply left immersed at rest in a pit during the same time. This hypothesis appears to explain satisfactorily the unequal duration of the combination of the hide with the tannin in these different conditions.

The electric process, besides reducing manual labor and hastening the operation, does away with the fermentation of the tannin and the hide, to which has always been attributed a final beneficial influence. Now, it is scientifically proved at the present time that fermentation is rather prejudicial than useful to the course of operations, while, at the same time, the tannin is decomposed into gallic acid and glucose—products that are non-utilizable by the hide.

ADVANTAGES OF THE NEW PROCESS.

The following table, which has been communicated to us, gives a summary, from the standpoint of duration, of the advantages that tanning by electricity possesses over the old chemical tanning:

Nature of the hides.	Duration of tanning. By the new process.	By the old process.
Light calf	24 to 32 hours.	3 months.
Heavy calf	48 to 60 "	4 to 6 "
Light cow and horse	72 "	8 to 10 "
Heavy cow and med. ox	84 to 96 "	10 to 12 "
Heavy ox	96 to 108 "	12 to 15 "

The renewal of the capital, the frequency of which is the recognized source of industrial profit, is therefore monthly in the Worms & Balé process, while it is annual in the old system. The renewal of the merchandise permits also in the electric process of more easily following the market price of leathers and hides and of taking advantage of favorable opportunities. The saving in tanning is about two cents per pound of shaved hide. The rendering, that is to say, the weight in dry and curried tanned leather obtained from a definitive quantity of hides in hair, is slightly in excess of that of the old method.

Finally, in order to tan 4,400,000 lb. of sundry hides, it requires, with the electric process, a special plant of 25 apparatus, costing about $20,000, and a motive power of from 50 to 60 horses. The cost of such an installation in the old system is about five times greater.

APPLICATIONS.

The process just described is applied at Paris by Messrs. Brion & Dupré; in England, by the British Tanning Company, and in the United States of America, Portugal, Brazil, Madagascar, the Argentine Confederation, and Venezuela.

According to the attestation of Messrs. Fortier-Beaulieu, President of Class 47 at the Exposition of 1889, and Gallien, Vice-President of the Syndical Chamber of Leathers and Hides, at Paris, the quality of the products obtained is satisfactory as regards durability and dynamometric strength. According to the same authorities, the rendering is 6 per cent. greater than that of the old process. Some experiments made by Mr. G. Hasenstein, at Verviers, have confirmed these results, and we find them confirmed also in various studies in the *Electrical Review*, of London, the *Elektrotechnische Zeitung*, the *Leder Industrie*, the *Gaceta Industrial*, of Madrid, and other technical publications.

It is certain that a very advantageous use of it will be made at all points of the globe, such as the saladeros of South America, for example, where extensive and rapid slaughtering of cattle is done.

From this point of view, there is a useful aspect of the question to be called attention to for France. We have already described in these pages the great frigorific installations of our intrenched camps established by the provident initiative of Mr. De Freycinet, minister of war. At Paris alone, where the daily obsidional ration of meat is calculated at the rate of three-fifths of a pound per inhabitant, a siege of six months involves a victualing of 264,000,000 lb. in fresh meat. This quantity of meat, the greater part of which in time of war, and a portion in time of peace, will be stored in the frigorific depots, corresponds to a large quantity of hides, utilizable almost immediately in the form of leather, thanks to the electric process of tanning. This, moreover, is what was affirmed by the official commission charged by the minister of war to look up and study at the Exposition of 1889 such objects, products, apparatus and processes as might be of interest to the army. "It is to France that it is necessary to return," said the report of this commission, "to meet with a method of which the extensive application would bring about a revolution in tanning. It is a question of rapid tanning, with the concurrence of electricity, of the Worms & Balé system. . . . Tanneries of this kind would be of great assistance in time of war, at the moment when a great want arose that needed prompt satisfaction."

CONCLUSION.

While giving an account, at the inception of the industry, of the researches that had been undertaken on the subject of electric tanning, we used in the publication of the results the reserve and circumspection that appeared to us indispensable. We think that we can now throw aside such reserve absolutely, by reason of the applications made and of the experiments whose results have been communicated to us. We have here a genuine progress of electricity, and it seems as if the quick process just described, replacing the interminable processes of old, will lead to certain advantages, among which the reduction in the price of the products would not be the least to be considered. The National Manufacturing Academy, of Paris, has given the Worms & Balé process the encouragement of a first-class medal. Mr. A. Muntz, the learned and competent chemist of the National Agronomic Institute, has given a report concerning it which is thoroughly favorable, and concludes that it constitutes a great progress by reason of the rapidity with which it converts hide into leather. The old processes, placed in comparison with this recent method, appear, upon the whole, to rest upon routine and prejudices. It belongs to our special manufacturers to put to profit the experience acquired by modifying their plant in time and as suits them.—*Le Genie Civil.*

THE TECHNICAL EDUCATION OF THE ELECTRICAL ENGINEER.*

By Professor DUGALD C. JACKSON.

PERHAPS it would be well to call my subject the "College Education of the Electrical Engineer," for it is strictly of the technical college course that I shall speak. We can truly affirm that the technical education of an engineer does not end until his work is ended, and the college course is but the commencement of it. It is neither possible nor desirable that the courses of study of electrical engineering students in the various schools should be alike, but a certain unity of purpose and treatment should be observed, and all can profit by the suggestions made by the practical man. With this in view, I present the subject to your attention as it is looked upon at the Engineering School of the University of Wisconsin. There is no originality claimed for the ideas presented, as they are based upon the recorded experience of some of the country's most successful practical men, and are virtually followed in such other engineering schools as make their courses thoroughly practical, and therefore, in the true sense, professional.

In order to enter the freshman class of the best engineering schools, the applicant must have a thorough common school education, including mathematics through ordinary algebra, a fair knowledge of English, a reading acquaintance with German or French, a little elementary physics and chemistry. In order that an engineer may use his abilities and training most advantageously, he should have a good general education, including a fair knowledge of literature, history, economics and certain elements of law. To have an average chance of proving successful, an electrical engineer must be well grounded in three sciences besides those gained in the common schools, and which cannot be classed as engineering. These are: Higher mathematics, as far as it may be practically applied in engineering; chemistry and physics (including elementary electricity and magnetism).

At the University of Wisconsin, during the first year the student is given a course of four subjects, continuing through the year. These are: 1st, English and rhetoric, with such reference to technical forms as seems desirable so early in the course; 2d, mathematics, beginning with higher algebra, passing through trigonometry and descriptive geometry, and into analytical geometry; 3d, advanced French or German, grammar and reader; 4th, manual training. In the latter, which continues during the following two years, we do not think it necessary or desirable for the student to spend sufficient time during his course to become a carpenter, machinist, blacksmith or foundryman. His future calling will probably not demand that his wages be earned in any of these trades; but they are tributary to his profession, and he must have an intelligent mastery of the tools and an appreciation of shop requirements. Mathematics are also continued through the second and third years, during which time analytical geometry, calculus and applied mechanics are passed through. All mathematics are taught with special view to future *practical* applications, and good use is made of the laboratory in applied mechanics. During the second year of the course, elementary chemistry and physics are disposed of, and here again the laboratory is put to good service. At the same time, work in draughting and the elementary designs of machines is begun. The third year is about half, and the fourth year wholly, devoted to what may properly be called professional studies.

It may here be asked, Of what use is the severely specialized education to the successful student in the engineering courses? The graduate does not become an engineer merely because he has successfully met the college examination. College cannot make an engineer, however practical the course of study may be. Practice has made thousands of good ones without the aid of the college, but I venture to say that these

* Abstract of a paper read at the general meeting of the American Institute of Electrical Engineers, Chicago, June 7, 1892.

would frequently have become more eminent if they had received a thorough technical college course. While theory alone, wherever learned, cannot make a practical man, it is the one who can follow the guide of theory along the paths of practical work and experience who makes the fully developed engineer. In order, however, that neither theory nor practice may lead him astray, he must have a *well educated common sense*.

The true object of the technical college is to teach the fundamental theories, with a common sense view to their practical applications, in such a way as to aid in a diagnosis, not by the application of a mathematical formula, but by comparing the accumulated experience of the practical world. Take two young men of equally *good* ability and equal age; put one through a thorough technical college course and the other through an apprenticeship of the same length of time. Finally, put them side by side in a working position, where they must work out their own salvation, and the college man will usually have more ambition and adaptability, and will outstrip his mate, though perhaps not at once. The college man may fall behind at first, but, having worked through the transition period, he will prove the winner. I venture to say this is the well nigh universal experience of those who have had the opportunity of dispassionately trying the experiment.

It is comparatively easy to properly teach the fundamental theories; hence it is so frequently overdone. It is not so easy to educate the judgment of a student in electrical engineering whose entire knowledge of his future profession has been acquired from the electric bells in his father's house, and who may never have examined a dynamo or storage battery until he visited the college laboratories. But it is wonderful how rapidly such students, when of good timber, absorb a beginner's information and a thirst for investigation. In this part of the student's education, the manufacturers and large users of electrical apparatus, who have become directly or indirectly interested in the work of the graduates, can assist with little direct inconvenience and much indirect advantage. In a properly organized technical school, as shown above, the student gains his fundamental theory during the first three years, and, if of good timber, he will absorb much of the practical methods of thought required for successful after-work. Moreover, a considerable part of the third year is spent in practical instruction. As the fourth year is wholly spent in practical training, or the education of the common sense, the student must have some acquaintance with the methods of commercial work before entering it, in order that he may properly profit by the instruction. It is impossible for many, and doubtless undesirable for the majority, to take a year from the midst of their college course for outside work. The summer vacation between the third and fourth years should, therefore, be occupied in some such employment as wireman on electric light or telephone construction, or better, in the station and repair room of an electric railway, under the eye of an appreciative superintendent. Three months spent in this work may seem very little, but it will do a deal of good in giving an apt student a fair idea of how far exact formulas will carry him. It is only by the generous co-operation of employers that students can obtain this summer's work. At first thought it appears that the employer gains no advantage from it, but upon careful consideration, an advantage is evident. To begin with, the properly trained student will not prove useless during the summer, and the satisfactory one will usually find employment, after graduation, with the interests of those who afforded him summer work, and who thus gain the benefit of his greater advancement during his last year at college. In a similar manner, the manufacturer gains an advantage from placing his apparatus in the technical school laboratories for *proper* use in instruction.

We can now usefully inquire into the specialized work that should be prescribed for the average electrical engineering student during his last two years at college. Up to this point, students in mechanical and electrical engineering courses have received virtually the same instruction. Here, we hold, with several others, their paths should diverge. The student of mechanical engineering goes into careful study of shop practice, designing and utilizing various types of machinery, and similar subjects. The electrical engineering student must receive a good working knowledge of the problems of the mechanical engineer, but he must above all be trained in the practical problems of electrical engineering. He, therefore, goes into a study of that which will aid most in making him truly an electrical engineer. His knowledge must all be based on mechanical laws, but he must be much more than one-tenth electrical.

Before reaching his truly professional studies, the student should gain, during his course in physics, a common sense grasp of the elementary notions of electricity and magnetism, and of the "all-pervading law of Ohm." The latter can be properly enforced in the laboratory by placing in the student's hands ordinary electrical instruments, such as bridges, galvanometers, amperemeters, voltmeters, etc. Before beginning his specialized work, the student's knowledge of Ohm's law and its common results should have become almost instinctive.

With due regard for his preparation, it seems best to arrange the professional studies for the average electrical engineering student in four divisions, thus:

1st. Electro-magnetism and its application to practical uses, with special reference to dynamos and motors.

2d. Electro-chemistry (including primary and secondary batteries) and electro-metallurgy.

3d. Alternating currents and alternating current machinery, including dynamos, converters, condensers, etc.

4th. The special application of the preceding divisions in electric light, power, railway, mining and other types of plants.

The last division is allotted about twice the amount of time given to each of the others.

While higher mathematics is a useful aid in each of the divisions, its limitations as an agent must be carefully set forth in the class room and laboratory. For the purpose of educating the judgment and fully defining the limitations of theories and mathematical deductions, the laboratory is indispensable. As much as one-half of the total time spent by the student under the direct instruction of the professors of electrical engineering should be devoted to the laboratory. This work, moreover, should, as far as possible, deal with commercial instruments and machinery, and actually follow the methods of testing and research used in practice. Physics, chemistry, mechanics, steam engine, hydraulics, dynamos, electrolysis, alternating currents, and other subjects, should all be properly represented by a commercial laboratory equipment, which is made useful in everyday instruction under the direction of a man who has had experience in similar commercial work.

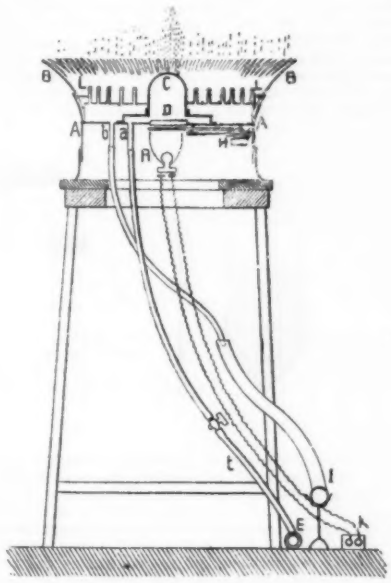
The student who satisfactorily completes a *proper* professional course at college, whether laid down in the college catalogue or carefully elected from that prescribed, is not likely to become one who "turns out results like a cornsheller, and never grows wiser or better, though it grinds a thousand bushels of them."

TROUVE'S PORTABLE LUMINOUS FOUNTAINS.

WE have already described Mr. Trouvé's portable luminous fountains, but we cannot pass over in silence the curious installation that this electrician courteously placed at the disposal of the city of Paris for the gala evening of the 14th of May, and which constituted one of the numerous attractions of the fete.

The great gallery which exists in the first story of the building (north side) gets its light from one of the court yards through nine wide windows, which had been concealed by high mirrors framed in tapestry and a profusion of flowers and varied foliage. It was before each of these mirrors that lovely wheat-sheaf jets of water, sparkling with red, green and yellow light, periodically varied, spirted during the entire evening.

The accompanying figure shows the new arrangement adopted by Mr. Trouvé to this effect. In a reservoir, A, is mounted a bell glass, C, with double bottom, provided at the upper part with nine apertures that give rise to as many jets of water. The water, which issues from a general pipe, E, placed upon the floor, and provided with tubulures with cocks, *f*, is led



TROUVE'S PORTABLE LUMINOUS FOUNTAIN.

by means of a rubber tube to *a* in the bell glass, C, and falls back into the reservoir, A, whenever it escapes through the tube C into the general waste pipe I. This latter is placed longitudinally upon supports of varying heights that give it a proper inclination.

Beneath the bell glass there is a glass, D, which gives passage to the rays of an incandescent lamp reflected vertically and parallelly by a parabolic reflector, R, whose focus it occupies. The current is derived from the conductors, K, placed in mouldings upon the floor. Finally, between the reflector and the bottom glass there is interposed a glass disk having variously colored sectors, to which a slow rotation at the rate of one revolution in three minutes is imparted by a clockwork movement, H.

The current is furnished at an intensity of one ampere under 105 volts.

The ornamentation is completed by a sort of bottomless box of painted tin, LL, upon the cover of which are fixed small holders designed to receive flowers. A flaring and notched rim, B, serves as a mounting to this elegant basket, while at the same time rendering the diameter of the reservoir wider.

The entire affair is placed upon a stool whose seat has a hole in the center, and which, along with the piping, is concealed by solid masses of foliage interspersed with flowers.

As we have above stated, nine fountains of this kind, spaced about eleven feet apart, and three and a half feet in height, played in the gallery, opposite the magnificent tapestries of the public furniture repository. The general piping thus had a length of a hundred feet. In order to prevent ram-strokes, which might have knocked out the glasses, D, small air reservoirs were soldered to each extremity of the conduit that introduced the water. This latter was siphoned from a small reservoir installed in the nearest fire station, constantly fed by the general piping of the city hall, and provided with a waste pipe. The pressure was thus reduced to the difference between the level of this reservoir and the jet orifices. The discharge pipe was connected with the corresponding station of the lower story.—*Le Genie Civil.*

GLAZING OF ROOFING TILES, BRICK, TERRA COTTA, ETC.*

MOST varieties of clay, particularly those which burn red, permit, even when thoroughly burnt, the percolation of more or less water. Hence, it is frequently observed that new roofing tiles, especially when not previously soaked, permit the rain to pass through to such an extent that the water not only appears in drops on the lower surface, but in sufficient quantity to wet the floor below. To be sure, the interspaces in the clay are gradually closed by mud deposited by the water, whereby the tiles after some time become impervious. But the same mud also produces upon the entire surface of the tiles, especially if the latter are not perfectly smooth, a coating which takes up dust and dirt. Hence, it frequently happens that nearly all the tiles, particularly upon low roofs, are covered with thick moss, which retains moisture, and the tiles on such places must necessarily rot. The partial object of glazing roofing tiles is to prevent this evil.

Besides, the great roof surfaces of deep buildings, such as churches, are monotonous, they offering to the eye but little interruption. This is still more the case in brick work, where the colors of the building are repeated in the roof. In the middle ages this evil was also recognized and overcome by covering the roof with glazed tiles of different colors. In building the Ludwig church, at Munich, V. Gaertner pursued the same course, and in covering the roof with glazed tile produced an effect which admits of comparison with a pearl-embroidered carpet.

Glazing consists in giving the exterior surface of the tiles a coating which at the temperature required for burning is converted into a glass-like mass. Hence, the glaze is a substance entirely different from the mass of the tile, and its durability and solidity depend much on the manner of its combination with the tile. The object of the glaze is, therefore, on the one hand to decorate the tile and, on the other, to render its surface impervious. The glaze mostly consists of a lead glass, colored as desired by the addition of metallic oxides. For ordinary pottery the proportion of silica to lead oxide is about 1:2, *i. e.*, mix about 1 part by weight of sand (frequently mixed with some clay) with double the weight of litharge or minium. The more sand in proportion to lead oxide is taken, the more difficult to fuse the glaze becomes. Litharge or minium melts at a comparatively low temperature and in a melted state dissolves the admixed sand, forming with it, if the substances are pure, a white transparent glass. According to the constitution of the sand, a varying quantity by weight of it is at the same time dissolved by the melting lead oxide. If the sand is coarse-grained, so that the surface exposed to the attack of the lead oxide is a small one, as compared with the mass of the sand, far less of it will, of course, be in the same time dissolved than when the exposed surface is greater. Hence the finer the sand, the greater the quantity which will in the same time be dissolved by the lead oxide. For this reason sand as finely divided as possible is a chief condition in preparing glaze, because if the grain is too coarse, the entire quantity of sand is not dissolved, coarser or finer grains, according to the time during which the lead oxide was allowed to act upon the sand, remaining behind.

Of still greater influence than the fine division of the sand is its chemical condition, since its fusing point plays a very important role as regards the quantity which during the same time can be dissolved by the action of the melted lead oxide. Pure silica in the form of finely pulverized quartz, flint, etc., is not fusible and hence will require the most time for solution by the lead oxide, because the latter will have to act upon a perfectly solid body. If silica in the form of a fusible mass be conveyed to the lead oxide, a much larger quantity of it will in the same time be dissolved, and it may be laid down as rule that a greater quantity of silica, of the same degree of fineness, will in the same time be dissolved by an equal quantity of lead oxide (as well as of other fluxes), the more readily fusible the mass is by means of which it is introduced. Nature furnishes us with an abundance of substances possessing all possible melting points, which, with a high content of silica, are more or less readily fusible.

There are sands with a very high content of silica which already slag (soften) at about 1,000° C., and hence readily dissolve in fluxes. Such sands, highly valuable for glazing purposes, are, for instance, found at Machlin, in Mecklenburg, and at Fuerstenwalde. These sands contain about 85 per cent. silica, 7·5 alumina, and 4 to 5 fluxing agents (ferric oxide, lime, magnesia, and alkalies), and on account of their ready fusibility and physical constitution (they contain many fine scales of mica, which offer a large surface to the solution) they dissolve readily and rapidly in fluxing agents. Besides these there are many clays with a comparatively high content of silica which fuse more or less readily. There are clays fusing at from 1,000° to 1,100°, which, in case such high temperatures are used in burning, yield by themselves good glazes, provided it does not matter as to color, and that the sole object is to make the articles impervious (earthy glazes for water pipes, pottery, roofing tile, etc.)

In the great abundance of substances rich in silica and more or less readily fusible which, on the one hand, are furnished to us by nature, and, on the other, as waste (slag, broken glass, etc.) by certain industries, there are so many suitable for glazes that with some professional knowledge a suitable choice can be readily made, especially as the readily fusible fluxes (litharge, potash, soda, boric acid, etc.) offer means of bringing the fusibility of the selected materials within a narrow limit, and thus exactly fit the fusing point of the glazing masses to the burning temperature of the kilns. With glazes for the purpose of decoration the conditions are much more difficult, the choice of substances through which the silica can be introduced being very limited. In this case not so much stress can be laid upon the ready solubility in fluxes as upon the purity of the materials. The naturally occurring substances rich in silica which are readily fusible generally contain more or less iron, by which they are colored dark. Hence if pure colors are to be obtained, sands, etc., containing iron have to be avoided and substances free from iron, but more difficult to fuse, selected. For glazes which are to serve for the pur-

* From Waldegg's German work on brick and tile.—*The Brickmaker.*

pose of decoration and show a determined color, sand free from iron (mica sand of the best quality, finely pulverized quartz or flint, etc.) will have to be used, and the proportion for the substances determined which is suitable for the burning temperature prevailing in the kiln. When a colorless lead glass suitable for the special variety of clay and the burning temperature employed has been found, the various shades of color are obtained by mixing the corresponding metallic oxides in proportions to be determined with the glaze.

For *dark brown to black*, pyrolusite (peroxide manganese) is used; for *green to black*, oxide of copper or chromium; for *blue*, cobalt oxide; for *yellow*, antimony oxide; for *red*, ferric oxide.

The application of the glaze to the tiles is as a rule effected by dipping, or to depressed places in ornamental or shape brick, or in architectural terra cotta, etc., by means of a brush, the articles being dipped either in a dry state or, still better, after having been burnt. If the surface of the tile is not sufficiently porous for the glaze to penetrate, a cementing agent (paste, gum arabic, etc.) is added to the latter to render its adhesion possible. The condition of the surfaces to be dipped or treated with the brush should be uniform, so that the glaze may everywhere adhere.

The principal defect shown by the glazes after burning are fine cracks. To prevent them, it is advisable to gradually decrease the content of fluxing agent (litharge, etc.) without, however, changing the composition of the mass, and thus make the glaze more difficult to fuse. The temperature must, of course, be increased, but fine cracks will thereby be entirely or almost entirely prevented. If, however, this remedy is not successful, *i. e.*, if fine cracks still occur notwithstanding the utmost possible reduction in the content of fluxing agent in the glaze and a corresponding increase in the temperature, changes as far as permissible must be made in the raw materials. It should be endeavored to make the mass meager with quartz sand or pulverized limestone (chalk) until the formation of fine cracks ceases. The so-called salt glaze is produced by from time to time throwing salt into the kiln during burning. The salt vaporizes at a high temperature and produces a glaze upon the surface of the articles.

The constitution and preparation of the clay are of special importance, particularly when the tiles are to receive a colored coating of glaze. In order to make the latter durable, it must enter into combination with the clay without the formation of fine cracks, bubbles, etc. The following mixtures, which have been established by careful tests in the brickyards of Munich, fulfill these conditions with the glazes belonging to them and may serve as guiding points.

I. DIFFERENT MIXTURES FOR THE TILE MASS.

1. Common clay	1	part by volume.
Red clay	½	" " "
Quartz sand	1	" " "
2. Marl	1	" " "
Quartz sand	1	" " "
3. Marl	1	" " "
Alum earth	1	" " "
Chalk	1	" " "
Quartz sand	1	" " "
4. Common clay	1	" " "
Red clay	1	" " "

Where there is a choice, the mixture given under 1 is to be preferred.

II. MIXTURES FOR GLAZES.

1. *Glazes for Nos.* 1 *and* 2 *of the tile masses.*

Lead ashes	12	parts by weight.
Silver litharge	4	" " "
Quartz sand	3	" " "
White alum earth	4	" " "
Common salt	2	" " "
Powdered glass	3	" " "
Saltpeter	1	" " "

2. *Glazes for Nos.* 3 *and* 4 *of the tile masses.*

Litharge	16	parts by weight.
Quartz sand	5	" " "
Powdered glass	4	" " "
Adamic earth	1	" " "

The intimate mixture of the ingredients of the tile mass is, of course, the first requirement. For this purpose it is best to finely divide each ingredient by itself, either by pounding or, better, by rolling, then to pass it through a fine sieve, and after moistening the entire mass with water to intimately mix it by tempering or rolling. The constituents of the glaze are also passed through a fine sieve and, after being intimately mixed, fused in crucibles to gloss, which, after cooling, is reduced to a fine powder by grinding with water. The powder is then prepared as required for application to the tiles.

The flat tiles which are generally used in Munich are moulded in the usual manner, and after being carefully dried they are sharply burnt for the first time. To free the surface of the tile from dust and other impurities acquired in burning, and at the same time to test whether the tiles contain pieces of lime, they are dipped, *i. e.*, placed in water, for one or two days. Any lime present is thereby slaked and causes the tile to crack, which of course would also take place after the application of the glaze, but the latter would be lost.

The glazing mass mentioned under 1 yields quite a white gloss, the whiteness of which may be considerably heightened by an addition of 20 to 24 lb. of tin to every 100 lb. of lead before reducing the latter to ashes. The coloring of both glazing masses is effected by the following additions, many tests being made as regards beauty, and especially durability:

Color	To every 10 lb. of glazing mass is added
Dark violet brown	½ lb. pyrolusite.
Violet	¼ lb. pyrolusite.
Green	¼ lb. copper ashes.
Pale blue	4½ drachms red cobalt oxide.
Golden yellow	½ lb. antimony.

These additions are not fused, but after pounding, passed through a sieve and then ground fine. By adding more or less of them, darker or lighter colors may be obtained. It may here be remarked that small tests should be made with all colors before coloring the whole mass of glaze, because the materials as obtained in commerce vary very much in regard to purity, the quantity of pyrolusite, for instance, required for the production of one and the same color varying very much according to the source from which the material has been procured.

For glazing, the surfaces of the tiles are rubbed clean; the glaze is then applied with a brush, the tiles being held almost perpendicularly over the vessel containing the glaze. They absorb the glaze so quickly that soon afterward they may be replaced in piles. Formerly the glaze was applied dry, but glazing by the wet method is better. With some experience and skill one workman can glaze from 5,000 to 6,000 tiles a day. When the glaze is applied, it is burnt in by a second slighter burning. In doing this special attention must be paid to the degree of heat in order to obtain uniform coloring, but further details regarding the operation cannot be given. An experiment made in Munich to prepare red tiles by coating the unburnt clay in a semi-dry, so-called leathery state, with pulverized reddle, then burning, and finally coating with a transparent glaze, did not succeed, since the glaze did not adhere and many tiles cracked. But a red glaze may be obtained by the admixture of a certain quantity of pyrolusite—between that required for dark violet brown and violet—and maintaining a fixed degree of heat, which can only be ascertained by experiments.

The illustrations, Figs. 1, 2 and 3, show the form and size of roofing tiles as well as the mode of tiling customary in Munich. Since, after tiling the roof, the surfaces of the tile which remain visible form small squares with sides $4\frac{3}{4}$ inches long, it is possible to produce by the use of different colors designs which relieve the monotony of the surfaces. It may further be remarked that on account of the considerable height and the small size of the squares, the indentations of the horizontal and perpendicular lines cannot be seen, but appear as inclined lines.

For plain glazing (dark brown or black) roofing tiles in a more simple manner, it is not necessary to first burn the tiles, but the glaze may be applied to the crude article. For the glaze it is best to use the Dutch directions, according to which 3 lb. of pyrolusite are taken for every 20 lb. of litharge, and as much clay is added that a ball formed of the clay floats in the glazing mass. For ordinary lead ore 6 per cent. pyrolusite suffices, and the glaze becomes perfectly black by adding 0·5 to 2 per cent. of copper oxide. In all compositions for glaze special attention must be paid that the mixture is not too readily fusible, so the tile itself has a chance to become hard by burning. Neither should it be too refractory, as otherwise the tile would be over-burnt before the glaze fuses. Hence, an accurate knowledge of the clay is necessary, and it should be determined by experiments how great an addition of one or the other kind of lead oxide it will bear in order to obtain the desired degree of fusibility. If pyrolusite is also to be added, the addition of sand or silica must be sufficiently reduced in order to restore the proper proportion. It must also be remembered that pyrolusite makes the glaze far more refractory than silica or sand, which readily fuse with the lead to a glass, and that hence the quantity of the one cannot be exchanged for that of the other.

The above mentioned substances are, each by itself, reduced to as fine a state as possible, then weighed off in accordance with the above stated proportions and then ground, first each by itself, and then mixed together, in a glaze mill with water containing fine clay in solution, until they feel milky to the touch and nothing like sand can be detected. The rapid progress of this operation is chiefly dependent on the quality of the millstones and the arrangement of the mill. Ordinary glaze mills are of fine sandstone, hard limestone, or granite.

Before applying the glaze, the surfaces of the raw tiles are rubbed clean, to prevent the glaze from being contaminated by sand or dust. When sufficient tiles have thus been prepared, the workman places himself between the tiles and a frame. Upon a bench in front of him stands a shallow vessel of a wide circumference filled with glaze. This vessel is called the glaze back, and may be of wood or, still better, of earthenware. After stirring the glaze with a large wooden spoon, the workman, taking with the left hand a tile by its upper portion, and holding it almost perpendicularly over the glaze back, places the spoon filled with the glaze about 1½ inches below the upper edge of the tile and moves it from the left to the right, allowing the glaze in the spoon to run over the tile. If the glaze is of the proper consistency, it is, in this manner, very uniformly distributed over the entire surface of the tile. A test with the finger nail is from time to time made to see whether the glaze has still the requisite thickness, water or thicker glazing mass being otherwise added. The tiles absorb the glaze with such rapidity as to permit of them being soon afterward replaced in piles. The finer the glaze has been ground, the better it remains suspended in water and the more rarely it requires to be stirred up from the bottom. A further reason for the necessity of grinding the glaze as fine as possible is that otherwise the pyrolusite does not thoroughly mix with the lead ore, which causes the appearance of streaks and stains after burning. With some experience one workman can coat 5,000 to 6,000 tiles with glaze per day.

Regarding tiles, the question whether it is more advantageous to glaze the crude or burnt articles is not so easily answered as for finer clay ware. When the tiles have been properly set in the kiln and the fire is properly conducted, the refuse by breakage, cracking, etc., should not be considerable. But with tiles the mishaps by fusing and baking together are more dangerous. With well constructed kilns the first should scarcely happen, especially when heating with small fires and the coal cannot directly act upon the tiles. The latter may be avoided: 1, by not applying the glaze too thick; 2, by the upper portion of the tile, where the knob of its neighbor leans against it, being left free from glaze; 3, by setting the tiles as perpendicularly as possible, so that they touch neither with their surfaces nor with their lateral sides, and so firmly that they cannot turn over during burning; and 4, by wiping off with the hand the greater portion of the glaze from the base of tile, so that there is no danger of their baking together on that point. With a second burning the tiles are, however, exposed to the same mishaps, and the consumption of double the quantity of fuel is mere waste.

The following process may also be recommended as the most simple glaze. Scatter finely sifted unburned lime and ashes over the half-dried tile, rub in well, and then allow the tiles to dry further. This mixture is a slight fixing agent and produces a glaze upon the surface.

Glazing with salt is effected by throwing the salt in the kiln, when burning is finished so far that the kiln is to be closed for cooling off. Since by this process a uniform glazing of all the tile cannot be effected, it is preferable to prepare a supersaturated solution of the salt in water and apply it to the tile before setting them in the kiln.

Regarding the setting of glazed tiles it may be remarked that a kiln should never be entirely set with them; because even with the best kiln it is impossible to distribute the heat so uniformly as to avoid fusing together, if it is insisted upon to everywhere fuse the glaze.

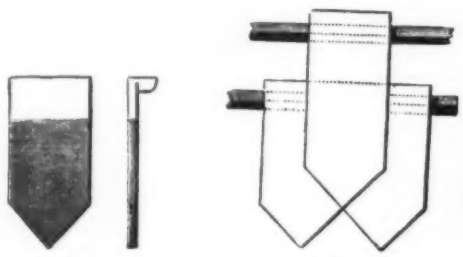


FIG. 1. FIG. 2. FIG. 3.

RICE: ITS MANUFACTURE.

By H. B. PROCTOR.

DIFFERENT varieties of rice are shipped at the different rice ports. From Rangoon, two varieties: Ngatsein grain, commonly called "Rangoon," is the best, and considered to be the standard variety, being the one most largely exported; Ngakouk, shipped from the same port, is a smaller grain, rather more friable, and usually quoted at 4½d. per cwt. less money in this country. Bassein rice is rather longer and thinner in the grain than Rangoon, as well as harder and more translucent; it brings generally 1½d. to 3d. per cwt. less money. Arracan rice is soft and chalky, worth about 6d. a cwt. less than Rangoon. Moulmein rice is similar in appearance to Arracan, but with a larger and flatter grain; it fluctuates in value above and below Rangoon.

There is a duty of 3 annas a maund, about equal to 6d. per cwt., levied upon both rough and cleaned rice exported to England or other parts of the world, except British India, to which it goes free. It is difficult to account for this "self-denying ordinance" and the strange inconsistency of permitting rice to go free to our Indian possessions and taxing the trade to our mother country to the extent of 10s. per ton.

The total amount raised by the export duty on rice in 1881 was £436,484, besides which it had to pay a large indirect duty in the form of the land tax. A strong feeling prevails in the minds of the Burmese and Indian officials that Burma pays more than her share to the imperial revenue; it pays more by far than any other state of the same population, no less than £1,097,569 surplus revenue having been sent to Calcutta in 1880–81, and this accounts for the agitation for the remission of the export duty on rice, which was advocated by Mr. Inglish and Baboo Doorga Churn Laha at the last budget meeting of the supreme council. The duty on Indian wheat was repealed in 1873; since then the wheat trade has increased so enormously as to become an important element in our supply. If English rice millers had the spirit and business capacity of Manchester cotton spinners, for instance, they would combine to petition the Indian secretary in support of the Burmese administrators, and this differential duty in favor of India and anachronous taxation on food would soon be a thing of the past, and the trade would have a corresponding increase at lower prices.

The Burmese are altogether too well off to take the trouble to mill much of their own rice by hand, when they can get it shelled and milled for them at a cheap rate at the rice ports. There are forty-nine large steam rice mills at Burma, twenty-eight at Rangoon, and seven at each of the other ports—Bassein, Moulmein and Akayab. Twenty of them have machinery for turning out white rice fit for foreign markets; the others can only prepare "cargo rice," such as is exported to be cleaned in Europe. Cargo rice consists of four parts of shelled rice and one part of paddy, which is mixed with it to keep it from heating and becoming weeviled during the voyage to Europe.

The trade returns for 1880–81 show an export of white rice equivalent to 10,131,000 baskets of paddy; cargo rice, equivalent to 44,491,000 baskets of paddy. The amount consumed for food and for seed in the coun-

try during the same time was about equal to the total exports.

The shipping season begins in January, and the bulk of the trade is over by the end of May, though cargoes continue to be shipped until later on in the year. During the busy season the rice ports are all life and animation. The rivers and creeks are crowded with boats bringing down the paddy to market; the brokers and buyers for the different mills put out into the stream in launches or small boats, and huckster and bargain with the owners of the paddy, and purchase the boat loads for their respective mills. The mills tear round night and day without ceasing, taking in paddy and delivering cargo rice and white rice to dhows and small steamers for the coasting trade, and to large steamers and sailing ships, which are loading for all parts of the world, Europe especially. The whole surface of the water is covered with the rice husk discharged from the mills. It hides the water from view, partly fills the creeks, and lies rotting and stinking on the banks, and days before a ship arrives in port she passes through masses of paddy husk that have floated hundreds of miles out to sea.

The two rice ports of England are London and Liverpool. A few years ago they used to mill two-thirds of the European imports, and the Continental rice ports the other one-third. Now, however, Bremen mills more rice than London or Liverpool, and the Continental trade continues to increase more rapidly than does the trade of this country. The poorer classes in northern Europe prefer rice, and find it cheaper than potatoes; whereas, the home consumption among the English working classses is extremely small. England would have no trade to speak of were she not the distributing center of the whole commercial world. It is cheaper to send cargoes of rice here to be milled, at cheap freight, when 40 per cent. of the article is consumed for home use, rather than to clean it in Burma, and to send it in large ship loads at more expensive freight direct to foreign markets, where the arrival of so much at once brings down the price 1s. or 1s. 6d. per cwt., besides the losses incurred from heating and weevils. As shown above, however, much cleaned rice is shipped direct, in the attempt to secure what the Burmese millers call the double profit. The result, so far, has been as follows: They gain about 3d. per cwt. on 10 per cent. of their exports, and have brought down the price obtainable for 80 per cent. about 2s. or 2s. 6d. per cwt. The 19 per cent. is the cleaned rice exported to compete in the markets of their largest customers; the 80 per cent. is the cargo rice, that the European millers cannot afford to pay so much for, now their trade has been so much injured. Should the Burmese direct trade further develop, we may expect the competition to do still more in this direction. We now come to rice milling in Europe. There is no need to describe in detail the elevators, creepers, hoists, etc., and the methods of handling the grain, which are common to corn and rice mills; so I here give a sketch, showing the order of the different processes, and a brief account of the principal machines used to operate upon the rice.

Sketch of the Processes of Rice Cleaning.

Process.	Products.
Sieve and Aspirator	Cargo Rice Stick, Stones, Refuse, Rice Dust.
Shelling Stones	Rice
Scouring Machine	Shelled Rice, Meal and Husk Meal
Blower	Rice and Husk Husk
Decorticators, one or more in succession	Shelled Rice Meal
Blower	Cleaned Rice and Chaff Chaff
Polishers in succession	Cleaned Rice Fine Meal
Blower	Cleaned Rice Chaff
Sieve	Cleaned Rice Fine Rice Smalls
Meal Machine	Mixed Meal Medium Meal
Sieve	Meal Rice Rice
Brush Machine and Aspirator	Meal Rice Offal Points II Smalls

Summary and Proportion for Ngatsein Rice.

Fine rice	64 per cent.
Smalls, II smalls, Points	18 "
Meal	15 "
Husk	3 "

Each rice miller has a system of his own, which is kept a profound secret, and which he seems firmly persuaded is capable of producing a far better result than can be obtained by any of his neighbors. A short conversation with some of our leading rice millers would go a long way toward shaking one's faith in Rochefoucauld's maxim: "A man may be cleverer than his neighbor, but he cannot be cleverer than all his neighbors." The different systems have much in common; the differences are more in the varieties of machines used than in the order of working. I have tabulated in the diagram as correctly as possible the systems now worked in the largest mills in London and Liverpool.

The end to arrive at is to obtain a white sample of rice, with the least possible breakage, the smallest abrasion[1]; consequently, the smallest quantity of meal, at the smallest cost for power and working expenses. The difference in value between the various manufactured products shows the necessity of strict attention to the smallest working details. Taking the present value of cleaned rice at 10s. per cwt.; smalls, 8s. 3d. per cwt.; meal, 5s. 6d., with an outturn of 100 tons per day, 1 per cent. more breakage means a loss of £525 a year; and 1 per cent. less rice and more meal, £825 a year loss. This accounts for the large sums of money that are constantly spent on the endeavor to discover machinery that will break less rice; still it is possible to get machinery that will save breakage and cost more than is saved in working expenses, wear and tear, and mechanics' pay. It may be taken as an axiom, the slower the rice is worked the less the breakage, but the larger the working cost per cwt. The difficulty is to hit upon the middle course, which avoids both extremes. In England, millers seem to prefer larger out-turn, with a trifle more breakage, than do the millers in the Continental towns.

The rice is generally elevated first to the top story of the mill, where it is blown or aspirated to get rid of the dust that would otherwise soon glaze the shelling stones and spoil their work. It is then sieved, either through a six-sided wire screen, or preferably through a long sieve supported on wooden springs, and worked transversely off a crank to get rid of sticks, straws and stones; sometimes copper coin, four anna bits and rupees, and on one celebrated occasion, a baby! But as Midshipman Easy's nurse said, to excuse her indiscretion, "It was only a little one." After leaving the sieve, the rice passes to the shelling stone hoppers.

Nearly all the mills in Europe use the same system of shelling rice. A pair of 6 foot stones of Derby gray or Newcastle stone, or any soft free sandstone, without pebbles, but large, hard, and even in the grit. The stones are dressed hollow at the eye, with a working face, perfectly true, of 9 inches wide at the rim; the stones are set about 3-16th inch apart, and work at about 120 revolutions per minute. The centrifugal force impels the grain toward the periphery, and as it passes through the narrow space at the working face, the grain is tipped up on end and the husks cracked off. When the stones run true, with good rice, the breakage is about three per cent. In some mills the rice is shelled twice and winnowed twice, but it is not apparent what is gained in the two operations.

In Burmese steam mills, where all the shelling stones used are sent from England at a considerable cost, they now use an artificial millstone made of emery and magnesian cement. Four parts by weight of No. 18 emery are added to one part of ground calcined magnesite (a rock carbonate of magnesia), and tempered with a saturated solution of chloride of magnesium. This mixture is laid about one inch thick on the iron plates made specially for the purpose; it sets in a few hours, and becomes hard enough for use in a few days. It is far more durable than the best millstone, and it always keeps a sharp face, owing to the difference in hardness between the emery and the cement that agglomerates it. Shelling stones covered with cork have been tried and given up in England. They are still used in Spain. In Italy a surface of hard wood set on end is sometimes used, like the Burmese native hand mills, but they are being gradually superseded by the common shellers, either of cement or stone. The shelled rice, together with the husk and meal, are next passed through a screen scourer or meal machine for the purpose of removing the meal, so that the husk can be winnowed the more readily from the grain. It is then winnowed or aspirated once or twice, and the shelled rice falls into hoppers ready for the decorticators, commonly called barley mills. Every miller in Europe employs different machinery for decorticating rice.

All work with secrecy. So it is difficult to find out what machinery they use, and impossible to tell which gives the best results. My own impression is that there is very little difference, and little to choose between any of the self-acting systems. The most primitive form of decorticator used in European mills was the stamper pot, on a larger scale. It consists of a vertical beam, about four inches square, with a stone pestle on the lower end, that is raised some three feet by a cam and dropped into an earthenware pot, nearly full of rice. The operation is repeated for ten or twenty minutes, until the rice is decorticated, after which the pot is scooped empty by hand, and filled with another charge. These machines are still used in the country mills in Spain and Italy, worked by bullock power or water power, but they get through so little work they have long since been superseded in steam mills.

An improved form of the same machine, however, has been introduced, and is still working in Copenhagen, Flensburg, and Antwerp, and in one mill in London. When used to work the rice first, followed by some form of barley mill, they seem to give very good results. The pot is of cast iron, lined with magnesian cement and emery, as described above. The pestle is of the same material, fixed on the end of a light iron rod, which is worked up and down by means of a crank and a connecting rod. The charge of rice is removed by means of a valve at the foot of the pot.

The barley mill first used for rice was the same old-fashioned machine that is used for making pearled barley; it serves the same purpose as the stamper pot, but does its work more rapidiy. It consists of a circular cheese-shaped stone, four feet diameter and two feet wide, that revolves about 280 revolutions per minute inside a wooden case covered with fine wire netting, revolving in the same direction about six revolutions per minute; about five or six inches space is left on all sides between the stone and the casing; this is half filled with rice while the casing is kept standing, and the machine is then started. In ten or fifteen minutes' time the rice is thoroughly decorticated, and the casing is stopped, emptied, refil ed, and started again with another charge, thus requiring a constant attendant.

The next improvement was to make the machine casings stop and charge themselves automatically when desired, requiring somewhat complex machinery, but giving more accurate and uniform results and saving manual labor. This led the way to continuous feed machines. They give the most certain results, and are the most readily controlled. The casings and stones are made seven or eight feet long. The rice is fed into the casings at one end, and at the other are slides near the periphery of the case, that can be opened or closed as desired. With the slides wide open, the rice passes through in a large feed, and is but slightly milled; when they are partly shut, the rice is worked more or less as desired.

The next improvement was to replace the long cylindrical stones with wooden or iron disks, or tables covered with emery composition, and fixed at a distance of a few inches apart upon the main spindle. The cement used at first was composed of emery, Roman cement, and glue, but it has been superseded by magnesian cement and emery, which is not only more durable, but is not so liable to become glazed and lose its working surface. This arrangement with emery tables requires more power to drive, because it gives nearly double the working surface of emery for the same size of case, but it puts through twice as much rice with less breakage. All modern decorticators use emery cement for a working surface. Stones have been driven out of the market. Not only are the machine repairs less, but the cement is so durable that it is estimated that one inch of cement will outlast some four feet or five feet of stone under the same circumstances.

In Bremen and Hamburg they adopt quite another system of decorticating. They use the outer edge of large stones, running like millstone runners, but larger in diameter at the top than at the bottom, and about eighteen inches thick. They are surrounded with an adjustable wire casing partly filled with rice, which is fed on the top of the stone. They are very cumbrous and heavy to drive, besides being liable to accident with too heavy a feed. In Burma they use, in some of the largest cleaned rice mills, an improved form of the same machine. The cone is about four feet deep by three feet six inches, and three feet in diameter, working inside a wire casing, leaving about three-eighths of an inch clearance on all sides, which can be increased or reduced as desired by raising or lowering the cone.

It has been lately patented in London, although similar machines have been worked in Liverpool for the last seven years. This patenting of old inventions, so frequent in the rice trade, is the result of working in the dark. Having described some of the forms of decorticators most used, I shall pass on to the next process.

The rice is again winnowed to rid it of the small chaff detached by the decorticators, and it passes on to the polishers. The form of polisher varies according to the taste of the miller who uses it, but they generally consist of a sheepskin-covered drum, revolving about 1,800 feet to 2,000 feet per minute at the periphery, inside a wire casing, which in some forms of machinery revolves slowly, too. The form most frequently used is that of an inverted frustum of a cone about the same shape as but larger in size than the decorticators used in Burma, and described above.

Another form of polisher is Sear's patent. Three wooden rollers, about two feet six inches long by one foot six inches diameter, are covered with sheepskin and arranged as in an ordinary roller mill for softening middlings, but farther apart. They work in a closed casing with an aspirator attached to carry away the meal that is removed by the action of the rollers. These machines are not so much used as the conical polishers, but they are capable of as good work when kept in good order. The rice is polished two or three times in succession. As it passes into the last polisher a minute quantity of indigo, toned down with rice flour to a pale blue, is generally added and brushed off again by the polisher. It gives the rice a bluish tint that looks more like white in the jaundiced eyes of the British public, who prefer this tint to the beautiful creamy whiteness, with a faint tinge of pink, that attracts the eye of those more accustomed to distinguish its excellences. On leaving the polishers, the rice is again blown or aspirated, and last of all separated into whole rice and broken rice or smalls. The sieves are usually made of perforated zinc. Perforated steel has been tried, but its increased cost gives it no advantage over zinc. The frames are made with every variety of motion. The one most in use is that suspended at the four corners, and worked with a circular motion by a central crank, with about four-inch throw. This motion keeps the grain more lively and assists in bringing the light, dead paddies, known as "quakers," to the surface, and delivers them over the end of the sieve apart from the whole rice.

The rice and smalls are then drawn off and weighed into bags, usually 2 cwt., ready for sale.

The different varieties of meal obtained from the various machines are mixed together and dressed through a meal machine to make "medium meal," which is sold for cattle feeding.

The rice, chaff, offal, and smalls coming from the tail end of the meal machine are passed through a small sieve, and the whole rice is returned to the elevators, which lead to the polishers, to join the main sample. The heavy offal and smalls are passed next through a Throop's brush, afterward a Child's aspirator, and graded into heavy offal, smalls, and points. The shude and chaff are sieved and winnowed a second time to recover the small particles of rice blown away with them at first, and mixed with the meal rice.

Lastly, the smalls drawn off at the sieve are ground to make rice flour. They are ground either by French burrs or Cumberland or other freestone that is not so hard in itself, but hard in the grit. The stones are dressed in the old-fashioned style. The usual dress is "nine threes" or "ten threes," with a good, clean furrow, and not too wide. The power required is much more than for wheat grinding. A pair of four-foot six-inch stones grind rather more than one sack of flour per hour, requiring about eleven or twelve horse power indicated to drive.

Most millers dress through wire machines; some few have adopted silks. The wear and tear of the silks is considerable, owing to the sharpness of the grit, but those who use silks say the expense is less for renewing the silk covers than for wire and brushes.

IMMUNITY AGAINST PNEUMONIA.

DRS. G. and F. Klemperer (*Berliner Klin. Wochen.*) have found that any nutrient medium in which the pneumococcus has grown, even after removal of the coccus itself by filtration, confers immunity against the pneumococcus-septicæmia. They also found that exposure to a temperature of 60° to 65° C., for one or two hours, made the immunizing solution more efficacious. The authors consider that the blood serum of protected animals renders harmless the poison (pneumotoxin) formed by pneumococci, and so, if introduced into the circulation, cures pneumonia already in progress.—*The Bacteriological World.*

WASHING GELATINE NEGATIVES.

THE washing of gelatine negatives is an operation that is but little understood except, perhaps, by a few. The general idea appears to be that the more washing the better, so long as accidents such as frilling can be avoided, yet there are many who devote only a few minutes to the process. Moreover, some of these latter are men of considerable photographic experience, and they say that their negatives do not suffer from the small amount of washing that they receive.

The aim of washing is to remove from the negative all the soluble matters left by the developer, the fixing bath or other solutions that may have been applied to it, and we may say that washing is perfect when there is nothing left in the film of gelatine but the image itself. We shall see that this perfection is impossible unless quite an abnormal amount of time and trouble are expended, and that, practically speaking, it is never necessary.

There are some people who wash their negatives after development, and before fixing, and we used to be taught that it was a dirty habit to do otherwise. We have never found any other advantage in this washing than that the hypo solution does not so soon get discolored. But we have never found our fixing solution spoiled by becoming dark before it was done with. For to be sparing of hypo is the height of unwisdom in negative making, and it may be relied upon that if a proper developer is used, and if the negatives have three or four changes of water at about one minute intervals, the fixing bath will not get discolored before it is time to reject it. In working small plates it is convenient to merely soak them for two or three minutes after development in a considerable bulk of water, and at once to pass them on to the fixing solution. This advice needs qualifying with the remark that the solutions used for developing and fixing should be of such a character that when mixed they will not lead to trouble, and this is easily secured with alkaline developers by making the fixing bath alkaline. It is our own practice invariably to add sodium sulphite and sodium carbonate to the hypo solution.

It is a great mistake to use an alum bath between developing and fixing, unless, of course, the plates are of such a poor quality that it is necessary to do something to prevent the loss of the negative from frilling or an analogous evil. Alum not only renders the washing before fixing a necessity, but it makes the operation of washing more slow by the toughening action it has upon the gelatine. It is desirable to keep the gelatine in as soft and permeable a condition as possible until all the necessary treatments with liquids are completed, for the harder the film is, the more slowly will liquids penetrate it, and the longer will it be necessary to devote to every operation.

By working in the way recommended, a negative requires only one washing, instead of the three that used to be insisted on, unless there is need for intensification or other after-treatment. The length of time that it is necessary to bestow upon this washing, to secure a practically clean film, must depend upon the thickness and hardness of the film and the manner of washing. We have found that the most thinly coated films in the market are fairly though not completely washed in two hours, no alum having been used. A plate that is decently coated needs longer, and a thickly coated plate may require six or eight hours' washing before one can feel confident that the soluble salts remaining in the film are practically negligible. On the other hand, a half or even less of this amount of washing is all that innumerable negatives have received, and we cannot point definitely to any consequent disadvantage, when the negative needs no after-treatment, though it is best to be on the safe side. It is fairly certain that the times given above will effect only an approximately complete removal of the salts from the film. As to the method of washing, this should be so arranged that the water acts equally over the whole surface. To put the plate in a dish under the tap is the worst way of any we know, even if a filter is used on the tap to prevent solid particles from impinging upon the film. Such washing is always uneven. By putting a half plate at one end of a 10×8 dish, or a whole plate at one end of a 12×10 dish, and letting the water come in at the other end, the washing is more even, but still faulty. An excellent though a somewhat despised way of washing is merely to soak the plate in water in an ordinary dish, and to change the water at suitable intervals. If the plate can be supported film downward in water, so much the better. But constantly moving water, such as can be obtained with a supply from a pipe, is very liable to work unevenly. We do not say that an evenly washed film is always necessary, but irregularities in this matter are likely to lead to other irregularities if any further work is to be done upon the negative. Local stains, patchiness, and similar evils are often due to such a cause.

But however well the washing is done it will not be complete, and it is at the end of the washing that the alum should be used as a hypo eliminator or decomposer if any intensification is necessary. We know very well that it is just now thought to be proper to say that hypo eliminators are not safe to use until all the hypo has been washed out, but this is not correct. We are also told that the best hypo eliminator is plain water, but plain water will not remove the hypo unless the washing is prolonged far beyond what would be considered excessive, and even if this were done there would be no certainty of its complete removal. Hypo eliminators are regularly used, and probably by those who object most to them, though it may be that they go by another name. Whether we call it an alum bath, a clearing solution or a hypo eliminator, matters but little, so long as the remaining hypo is decomposed by something. If a negative is subjected to a fair washing, and is then soaked for twenty to thirty minutes in an alum solution, and is washed again, it will be in fit condition for any further operation upon it—it will be free from hypo. An acidified alum solution will work more quickly, because it will not harden the gelatine so much; acid alone will work more quickly still, but it is more dangerous to use. The fact that acids tend to soften gelatine leads to the desirability of adding hydrochloric acid to the mercuric chloride used for intensifying, as the mercury salt alone would make the film very hard and render the washing away of the excess of the salt tedious almost to impossibility.—*C. J., in Photography.*

IMPACT, OR THE FORCE OF PERCUSSION.

By G. D. HISCOX.

THE force of a blow from a hammer in the hand, of a drop press, a pile driver, a steam hammer, a rock drill; the falling of solid bodies, the water ram in pipes; and the power of projectiles, produce effects deducible from the general laws of dynamics applicable to such work, and which have not been brought together under one general head, are worthy of a more close association than has heretofore been given to one of the most effective elements of mechanics.

The power of a hammer, which has not as yet been classed among the "mechanical powers," without doubt deserves the place of honor as the most ancient and, in many respects, the most wonderful mechanical power known. We daily see the results of its surprising force, effected without the complication of levers, wheels or wedges; and apparently having some innate power superior to and independent of the principles of mechanics as commonly studied.

In order to enable any one to make the complete computation, for the velocity of a drop hammer in the drop press, a cushioned steam or air hammer; or the monkey of a pile driver, when the velocity is due to gravity only; the power of impact at the moment of giving the blow may be ascertained from the known height at which the velocity of fall commences. The effect due to cushioning of steam, air and spring hammers will be an acceleration of velocity due to the gross pressure at starting, and which will be described later on.

The square root of twice gravity $\left(\sqrt{64{\cdot}33}\right)$ multiplied by the square foot of the height $\left(\sqrt{\text{height}}\right)$ in feet; $\sqrt{2g \times h}$, or $8{\cdot}02 \times \sqrt{h}$ = the velocity in feet per second at the instant of impact of a falling body.

Then one-half the square of the velocity $\times$ by the $\frac{\text{weight}}{\text{gravity}}$ $\frac{v^2}{2} \times \frac{w}{g}$ or more simply the height of fall $\times$ by the weight gives the number of foot pounds due to the fall; and the distance at which the force of the blow is arrested is the measure of the force of percussion or impact. It is as much more than the momentum in foot pounds as the distance of arrest bears to a foot. Thus if, at half a foot, the impact is twice the foot pounds, if one inch, it is 12 times, and so on through the fractions of an inch. At $\frac{1}{4}$ inch it is 48 times, and $\frac{1}{8}$ of an inch it is 384 times. This latter move represents the impact of hardened surfaces, where the elasticity of the metals largely represents the small movement at impact, and of which the rebound of a hammer from the face of a hardened anvil represents the reactive effect of the foot pounds due to the momentum of the fall.

A small hammer swiftly wielded will accomplish that which would otherwise require a direct pressure of several tons. Seeking the cause of its mystic power, the principles of accumulated work or energy stored in weight and velocity will account for the varied effects we obtain.

In striking a blow with a hammer upon the head of a chisel there are two forces brought into action, viz., the force of gravity and muscular force, to increase the velocity, so that at the instant of striking, the hammer may have a velocity of from 20 to 50 feet per second; the effect at this moment is the same as if the final velocity had existed throughout the whole of the stroke. Assuming 32 feet per second as the actual velocity at moment of impact, then the force will be the same as if the hammer had fallen from a height of the square of the velocity, divided by twice gravity

$$\left(\frac{v^2}{2g}\right) \text{ or } \frac{32^2}{64{\cdot}33} = 16 \text{ feet.}$$

With a hammer weighing 2 pounds, then, the accumulated work or energy will be $16 \times 2 = 32$ foot pounds.

Supposing that the face of the hammer moves one eighth of an inch after touching the head of the chisel before the energy is all absorbed, then the result will approximately be the same as a direct pressure or dead load of $32 \times \frac{12}{\frac{1}{8}} = 3{,}072$ pounds, or upward of $1\frac{1}{2}$ net tons; but this is only partially true.

More correctly it would be an average pressure of 3,072 pounds, being considerably more at the commencement of contact with the chisel and reduced at the end of the chisel cut to the mere weight of the hammer and chisel.

The hammer may be a self-adjusting mechanical power; for if the material be harder, so as to give more resistance to the chisel, the cut will not be so great, and therefore the force of percussion will be greater. For instance, if the movement of the chisel, as above stated, had been only one sixteenth of an inch, the force would have been doubled or equal to a pressure of three tons instead of $1\frac{1}{2}$ tons.

But there is a limit to the effect; otherwise the blow would be measured by thousands of tons, until the rigidity of the mass receiving the blow was balanced by the elasticity of the material giving and receiving the blow. This is beautifully illustrated when striking the hardened face of an anvil with a hammer, where nearly the whole force of the blow is returned in the rebound of the hammer.

The intensity or quality of a hammer blow is of great importance in the various materials upon which it is used; the man of iron and steel using a quick blow, while the man of stone uses a slower blow with a heavier hammer, or the elastic mallet, which gives a pushing blow. Each method being the best, in its way, because suited to the material operated upon.

An interesting illustration of the power of a hammer is shown in an experimental driving of a sixpenny nail into a pine plank by direct pressure; being

$\frac{1}{4}$ in.	by a pressure of	24	pounds
to $\frac{1}{2}$ in.	" " "	76	"
to 1 in.	" " "	235	"
to $1\frac{1}{2}$ in.	" " "	400	"

And then drawn out by a direct pull of 327 pounds. By using a drop hammer falling one foot by gravity only, and weighing 6·275 pounds, forced a sixpenny nail into a pine plank as follows:

1st blow	0·8 in.,	equal to	94	pounds	pressure.
2d	" 0·3 in.,	" "	251	"	"
3d	" 0·24 in.,	" "	314	"	"
4th	" 0·16 in.,	" "	470	"	"

The pressures here shown are equivalent to equal blows of a one pound hammer striking at the velocity of 20 ft. per second.

The "drop press," so much in use in the manufacture of jewelry, the stamping of brass and tin ware, the forging of a vast variety of articles in iron and steel to exact forms, is one of the most wonderful combinations of nature's greatest power, gravity, acting upon an inert mass in the performance of work.

Its range of power in compressing and shaping metals is from the mere weight of hammer to thousands of tons, as may be readily shown by the computation of its elements. Under its immense pressure all plastic metals are made to flow, nor do they cease to flow until the power of the hammer becomes limited by the elastic properties of both anvil and hammer. With a drop weighing 100 pounds and falling one foot with a crushing yield of the metal in the die of $\frac{1}{16}$ in., the static pressure, after deducting 10 per cent. of the computed pressure for friction of the ways, strap or carrier, will be 8,640 pounds (over 4 tons), while at another equal blow with a yield of only $\frac{1}{32}$ in. the pressure will be twice as great, or over 8 tons. It is in the finishing stroke that the impact of a blow tells its work, for when the drop is raised 4 ft. to give the work the fine impress of the die, and there is but a yield of $\frac{1}{32}$ in. in the compacting of the metal and elasticity of the anvil and drop, the enormous pressure of over 64 tons will have been instantly attained; all from the single and momentary effort of one man.

In the larger power drops used for raising tin and sheet iron ware, from one to two hundred tons, and in forge presses of this type, a three hundred ton blow is within practice. In the view of power derived from percussion the pile driver becomes one of the most valued adjuncts in engineering work, not only in the work of establishing foundations of pile work, but of indicating the load that the piles can carry by the dynamic effect of the finishing blows. It is here that the force of percussion is transposed into static pressure, from which is derived the factor of safety for the bearing load of a pile foundation.

As the monkey or hammer of a pile driver acts by the force of gravity alone, less the friction of the guides and air, for which a deduction of from 8 to 10 per cent. should be made, the computation for energy is the same as for the drop press, only more in magnitude of the falling body and increased velocity from the greater height.

The formula for the velocity of the monkey or ram for any given fall is the square root of the height multiplied by twice gravity, $(\sqrt{h \times 2g}) =$ velocity in feet per second.

The square of the velocity $\times \frac{1}{2} \frac{\text{weight}}{\text{gravity}} =$ the momentum in foot pounds.

An easier worked and equally accurate formula is the weight multiplied by the fall in feet—$(w \times h) =$ the momentum or foot pounds of work, and this product multiplied by the sinking distance of the pile in fractional parts of a foot represents the force of percussion or impact, less about 10 per cent. for friction of the guides of the pile driver and the air. Assuming a fall of 25 feet for a 2,000 pound ram, the momentum is $25 \times 2{,}000 = 50{,}000$ foot pounds. If the pile moves 6 inches, the static force of percussion equals 100,000 pounds; if only 1 inch, 600,000 pounds is the static pressure, from which 10 per cent. deduction may be made for friction, and a further deduction for the elasticity of the pile must be made in order to arrive at the safe load that the pile is intended to bear.

The elasticity of piles varies in amount with their length, and may be approximately observed by the rebound of a mark near the top and which should also be used to gauge the progress of the pile in the last few blows of the ram. As an example, assuming the pile mark to move down $1\frac{1}{2}$ inches and recover $\frac{1}{2}$ an inch, then the whole movement, or $1\frac{1}{2}$ inches, is the real value of the resistance, and is the fraction of 1 foot to be used as the multiplier for the static load; then the 50,000 foot pounds should be multiplied by 8 instead of 12 for the 1 inch gain in the progress of the pile. The static pressure will then be $8 \times 50{,}000 = 400{,}000$ pounds $\times$ 0·90 for loss by friction = 360,000 pounds, or 180 tons as the ultimate static load of the ram.

For the safe bearing load, the ultimate load should be divided by 10, leaving 18 tons as the limit of safe load of the pile. In pile driving for heavy foundations, the ram should be as heavy as possible with a moderate fall, as the elasticity of long piles absorbs so much of the work of the lighter ram used at the velocity due to a higher fall that its energy by the observed effect upon the progress of the pile is far less in static pressure than the same energy derived from a larger ram at less velocity.

When we reach the domain of "power behind the throne" and have steam and compressed air to aid the force of a blow, the elastic force behind the hammer gives it the velocity due to impractical height of fall in large bodies, and thus adds power to a short stroke, and enabling that control over the movements of a great steam or air hammer so necessary for the successful working of the immense forgings now being made. The later improvements in hydraulic forge hammers have now enabled the enormous hammer pressure of 4,000 tons to be utilized in making the forgings for modern ordnance.

In computing the power of direct-acting steam or air-driven forge hammers, we have the elements of the initial pressure, from which must be deduced the mean

pressure throughout the stroke; the weight of the hammer, rod and piston, and the length of stroke; from which to obtain the positive work of the hammer per stroke; against which are the back pressure from a cushioned blow, or the constant retarding pressure from the exhaust with a free stroke, together with the friction of the moving parts, which constitute the sum of the deductions to be made from the computed positive impact of the hammer.

For the purpose of arriving at the approximate power of percussion of a steam hammer, we may assume for the conditions of computation a weight of 4,000 pounds for the piston, rod and hammer, with a diameter of cylinder of 20 inches and a maximum stroke of 3 feet, with boiler pressure at 100 pounds.

From the nature of the work of a steam hammer, both the pressure and stroke must be extremely variable below the limit of greatest capacity, so that for the maximum effect we have:

W = Weight of hammer, piston and rod = 4,000 lb.

S = Greatest stroke of piston = 3 ft.

P = Pressure, area of piston 314 square inches × 50 lb. assumed mean pressure = 15,700 lb.

g = Gravity, or the velocity of a falling body at the end of one second of time = 32·16.

m = Mass = Weight divided by gravity =

$$\frac{4{,}000}{32{\cdot}16} = 124{\cdot}378.$$

f = Total accelerating force P + W = 19,700 lb.

a = Acceleration =

$$\frac{f}{m} = \frac{P + W}{m} = 158{\cdot}388.$$

v = Velocity of impact =

$$\sqrt{2\,a\,S} = 2\,S\,\frac{P + W}{m} = 30{\cdot}827 \text{ ft. per second.}$$

E = Energy =

$$\frac{m\,v^2}{2} = \frac{m\,2\,S\left(\frac{P + W}{m}\right)}{2} = S\,P + S\,W = 59{,}100 \text{ ft. lb.}$$

If the energy of the blow is arrested by the compression of the forging and the spring of anvil in a distance of one inch from the point of contact, the measure of the force of percussion must be multiplied by the distance of arrest in fractions of a foot for its true value. Thus for one inch 12 × 59,100 = 709,200 pounds or over 354 tons = the static pressure due to percussion.

In striking a cold mass of iron upon the anvil block with a yield of only one quarter of an inch the enormous pressure of over 1,400 tons would be attained.

From the total accelerating force, the friction of piston, rod and slides should be deducted; amounting in well constructed direct-acting hammers to from 3 to 5 per cent. The resistance to the power of a full hammer blow from the back pressure of the exhaust is of some importance, and may possibly amount to from 3 to 5 pounds per square inch or about 10 per cent. on the total effect, as above stated.

The effect of cushioning of the piston is a beautiful illustration of the control that can be made over an intense mechanical force, that by the mere movement of a hand may have its power varied from 0 to a percussion pressure of over 1,300 tons.

The action of a rock drill is somewhat unique in its persistence in overcoming the resistance of the various kinds of rock to its efforts to penetrate their depths. It does its work not so much by the high percussion pressure of a single blow, but rather by the quick repetition of blows just suited for effective work, and to accomplish a given depth of hole in the shortest possible time. Its peculiar valve gear and short stroke make its percussive force almost wholly due to pressure on the piston and which is made thoroughly controllable at the hand valve and feed screw. By this means the drill may be run at a stroke and pressure that gives the fastest cutting power; and as this may not be its longest stroke, which cushions the blow and reduces the number of blows per minute, a medium of from 75 to 85 per cent. of the full stroke is found to be most effective.

The friction of the drill steels in the hole, added to the friction of the piston rod, piston and rotating device or rifle bar, is a serious drawback to the otherwise large theoretical power of percussive pressure in the rock drill.

As an example of the theoretical percussive blow from a medium size rock drill of say 3 inches diameter of piston, running at 60 pounds pressure with 5 inch stroke, having an effective piston area, after deducting the area of the rifle bar, of 6 square inches, weight of piston and drill steel 50 pounds.

The friction of the pipe and passages, throttling by the valve and back pressure from the exhaust, together with the following of the steam or air pressure for three quarters of the stroke, will reduce the mean pressure to 40 pounds.

Then by the formulas as given for the steam or air hammer, the energy of the blow will be the total mean pressure on the piston multiplied by the stroke in fraction of a foot, plus the stroke multiplied by the weight or 6 sq. in. × 40 pounds × $\frac{5}{12}$ + $\frac{5}{12}$ × 50 pounds = 120·8 ft. pounds.

Then if the drill penetrate the rock $\frac{1}{8}$ of an inch at each stroke, the theoretical effect of percussion will be $\frac{12}{1/8}$ or 96 × 120·8 = 11,596 pounds, or over 5½ tons static pressure.

A large allowance from the theoretical effect must be made for the actual effect, by the assumed value of the friction of the drill steel on the sides of the hole, and other moving parts, as well as for the resisting effect of water and debris of drilling, which always more or less clog the drill hole.

The average running time of drills on open rock work is about 5 hours per day, and the average of 250 strokes per minute or 75,000 strokes per day is probably a fair average day's work. This at $\frac{1}{8}$ inch depth of cut and 10 strokes to make a circuit of revolution of the steel to complete the cut will represent $\frac{75{,}000}{96} = \frac{781}{10}$ = 78 feet lineal depth of holes for a day's work in rock of medium hardness — limestone. In granite from 50 to 60 feet is about an average day's work, owing to the less penetration of the drill per stroke, while in marble, with dry short holes, a very much larger depth of holes, 200 to 250 feet, has been drilled. In this kind of work the actual running time of the drill is increased by the increased facilities of adjustment from hole to hole and the use of only a single drill steel.

The effect of water ram in pipes is often of so serious a nature as to endanger a water works supply by the bursting of a pipe at the point of greatest pressure from the percussion due to sudden arrest of motion. This is notably so at the first letting on of the water, at which time the greatest care should be taken to open the gate but little at a time until all the lines of pipe are filled. The quick closing of fire hydrants in town water works with long lines of small pipe creates a water ram that is felt throughout the entire distributing pipes, and by repetition tends to disturb the joints and produce leaks with possibilities of rupture at the point of greatest percussive pressure.

The use of plug and spring bibbs for drawing water in buildings produces an excessive hammering, which, unless amply provided with air chambers, tends to burst lead pipes by progressive enlargement.

Hence the necessity of air chambers in all confined water systems, where there is liability of water ram by sudden stoppage of the flow.

To illustrate the extreme effect of suddenly closing a bibb on a water pipe under pressure and without an air chamber. Assuming a 2 inch pipe 100 feet in length from a main, under a head of 100 feet, or 43 pounds pressure per square inch, with a ¾ inch bibb at the extreme end.

We find that the spouting velocity of the water through the bibb by the formula $0{\cdot}62\sqrt{2\,g\,h} = 49{\cdot}72$ feet per second, and as the 2 inch pipe is 7·12 times the area of the ¾ inch bibb, the velocity of the water in the 2 inch pipe will be $\frac{49{\cdot}72}{7{\cdot}12}$ = nearly 7 feet per second.

For the weight of water under motion, from which we derive the force of percussion, is

$$\frac{\text{length} \times \text{area}}{144} = \frac{100 \times 3{\cdot}14}{144} = 2{\cdot}18 \text{ cubic feet,}$$

which multiplied by 62½ = 136¼ pounds, and as stated before $\frac{v^2}{2} \times \frac{w}{g}$ = the foot pounds of effect.

Then $\frac{7^2}{2} \times \frac{136{\cdot}25}{32{\cdot}16}$ = 103·63 foot pounds, or the momentum of the moving column of water in the pipe. The sudden shutting off the flow will increase the pressure due to the momentum in proportion to the fraction of a second due to the closing of the bibb. If it is one second, the pressure due to percussion will be 103 pounds; if half a second, 206 pounds; and if ¼ of a second, 412 pounds, or nearly 10 times the pressure due to its static head.

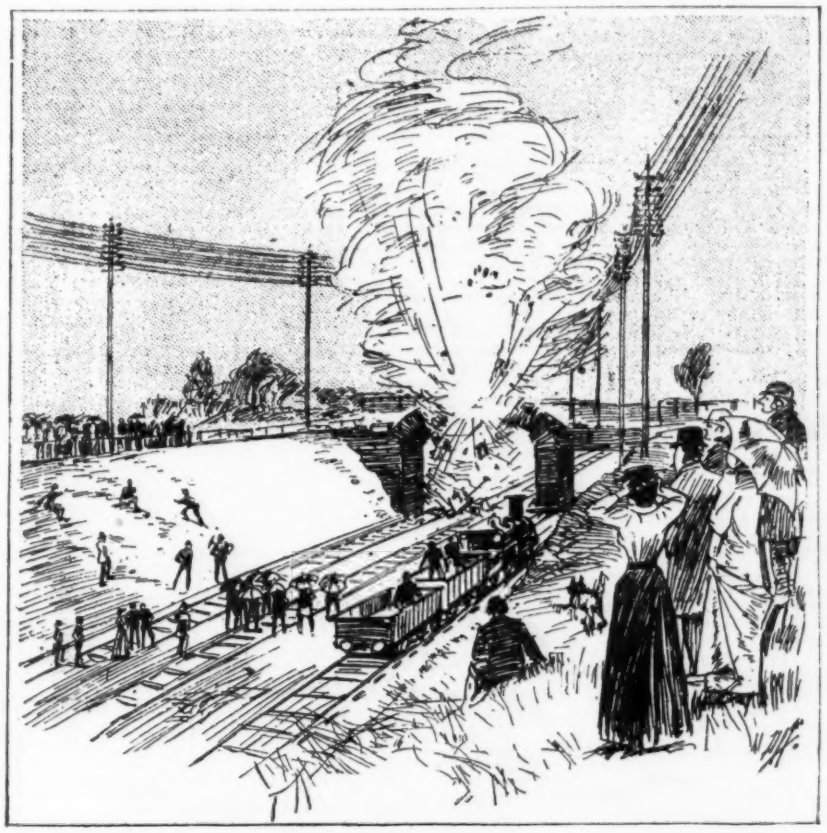
The penetrating power of a shot or shell projected from modern ordnance is subject to computation from its known or assumed muzzle velocity by the same rules as for other bodies, when the velocity at impact and the weight are given. The difference between the kind of velocity in a projectile and a body moving by gravity alone, or a combination of gravity and elastic force, being that a projectile starts from near the muzzle of a gun with its greatest velocity and gradually loses it by the friction and resistance of the air in front and held back by a perfect vacuum behind it; because, as air flows into a vacuum at a velocity of 1,300 feet per second, a shot moving at a greater velocity than 1,300 feet moves faster than the air can flow in behind it, and, therefore, a perfect vacuum is maintained behind any projectile moving with a greater velocity than 1,300 feet per second.

This may be counted as a constant pull of 14·7 pounds per square inch for the entire area of the rear end of a shell. For a 10 inch shell, equal to 1,154 pounds.

The form of the point has much to do with the front resistance, so that with a following vacuum, the impact of the air at the front, together with the surface friction, there is an average loss of velocity of 17 per cent. at a range of 3,000 yards and 30 per cent. at 6,000 yards.

A 1,000 pound shot having a muzzle velocity of 2,000 feet per second will have but 1,400 feet striking velocity at 6,000 yards (3½ miles). Its foot tons of momentum or energy will decrease; not in proportion to the percentage of velocity, but in reality as the square of the velocity.

As an example of the great loss in penetrating power at long range, a 1,000 pound shell with a muzzle velocity of 2,000 feet per second will have near the muzzle, as in the armor plate trials, a striking energy, by the formula $\frac{m \times v^2}{2}$ as before explained, of over 27,000 foot tons; but after traversing a trajectory of 6,000 yards (3½ miles) will have a velocity of only 1,400 feet per second and a striking energy of 13,600 foot tons, a little more than one-half its penetrating power at close range.



WIDENING OF THE GREAT WESTERN RAILWAY NEAR SHOTTESBROOKE.

In the late trials of 14 inch nickel steel armor plate for the battle ship Indiana, now under construction, the 500 pound projectiles with 140 pound charges, giving velocities from the muzzle of our new 10 inch steel rifles of 1,400 feet per second, made but slight indentations in the plate at close range, and rebounded without disturbing the plate for future resistance.

As the charges do not much exceed this in actual battle, the fighting distance being greater, or seldom at close quarters, we can safely assert that the fighting energy of our naval armament has arrived at an equality, if not superiority in the penetrating power of its guns and resistance of armor, to any nation that might wish to antagonize us.

Note the failures of the great guns in Europe.

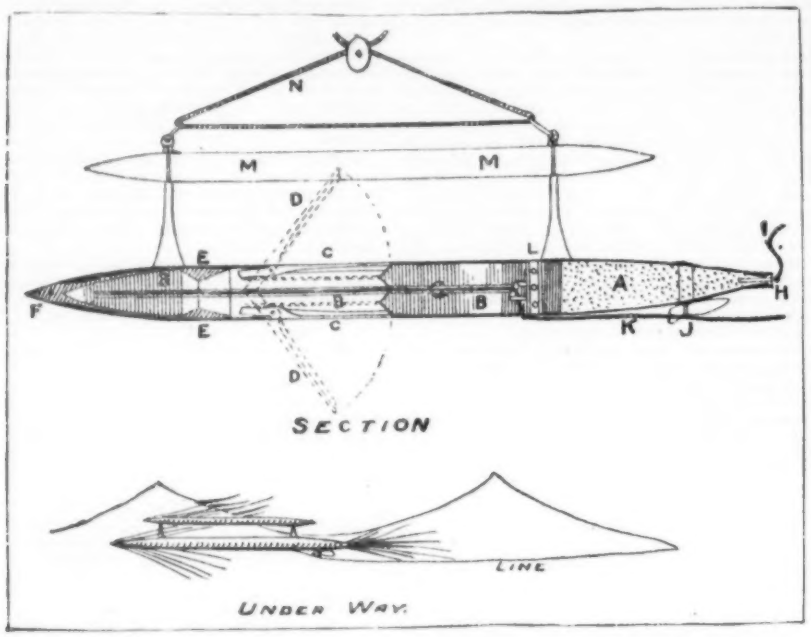
BLOWING UP A BRIDGE.

THE widening of the permanent way of the Great Western Railway near Shottesbrooke has necessitated the demolition of a number of bridges over the line in that neighborhood. The work has been in progress for some time, but it is now nearing completion, the last of the bridges in the way having been blown up by dynamite on Sunday morning May 15, just after the 11:27 train for Maidenhead had passed. A number of spectators were present to see the explosion, many of whom had come from a long distance.—*London Graphic.*

AT a meeting of a farmers' club in Illinois an address was made advocating the constructing by rural communities of light railways along the section lines, with a switch to every farm, in lieu of the building of macadamized roads. The author declared that the day of transporting freight by horse power has passed, and that it will cost more to place the mud roads of the West in proper condition for teams than to build light railways.

LIFE-SAVING DEVICES.*

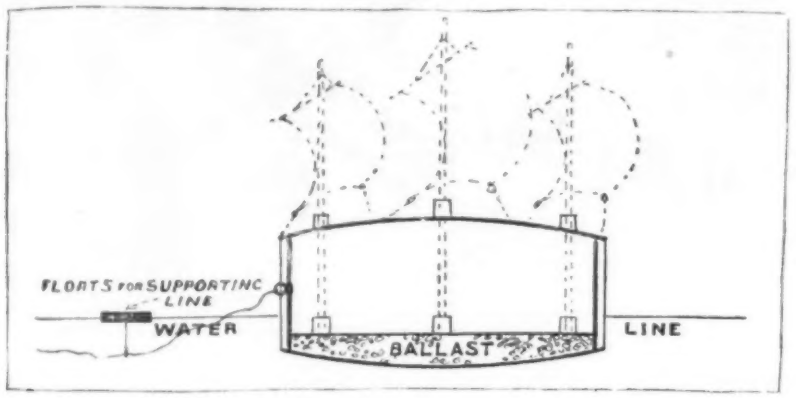
THE first sketches below show a line-carrying fish torpedo designed by Mr. William Hodgkinson. It is intended to carry from two and a half to three miles of line, and an automatic anchor and rudder, and, with its motive power complete, all in 8 ft. to 10 ft. Its shell and the float are to be of copper, and the anchor and connections of best cast steel. The line is to be coiled to run from forward aft, and thus to counterbalance waste in the powder chamber. A speed of thirty miles an hour for two miles is to be obtained under favorable circumstances with this form of construction.



A LINE-CARRYING FISH TORPEDO. (From the designs of Mr. W. Hodgkinson.)

The inventor says, "It may be swung clear of a vessel and aimed ashore, and the firing lanyard pulled. Then when ignition is well begun, slip the launching line, and let go all but a life line, which should be fast to a large coil of small line on deck. The simplicity of this will commend itself to seamen, for 'Jack' is not capable of handling electrical apparatus, even should a ship have it." The anchor would be spread by the head of the fish being driven aft by contact with the ground. This would slip a ring as a wedge under the arms of the anchor and lock them, or by hauling the line aft the points would be raised and catch the ground. The motive power suggested is slow-burning powder, and the principle that of the rocket, the limits of range being the limits of line and charge of powder. In the sketch of the section of the torpedo, A is a chamber filled with slow-burning powder; B, a line (or wire if telegraph service is required); C, anchors, the dotted lines, D, showing them expanded; E, expanding ring for opening anchors; F, contact plungers; G, line running through center of coil aft; H, primer; I, firing lanyard; J, automatic rudder on line rove through tiller; K, life line; L, double bulkhead with holes for water circulation; M, float filled with raw cotton or cork; N, slip for launching from yardarm or boom.

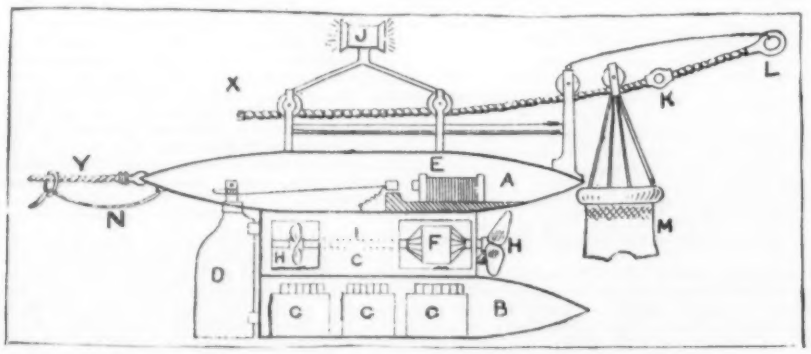
The design sent by Mr. C. W. Hunt is of a watertight barrel, properly weighted with any solid ballast, securely battened down to prevent the rolling of the barrel and to keep it steady in the water. At one end is attached a fine steel wire line, to be paid out by those on board the wrecked ship, and this line is supported by wood floats to prevent it from sinking to the bottom. These floats could be placed at proper distances as the wire is let out. The object of the floats is to prevent entanglement with rocks or sandbanks. The barrel would be drifted in by wind and tide, and could then be picked up by the lifeboat or allowed to float ashore. The dotted lines in the sketch represent sails, which could be provided for and added when the wind was favorable, the sails in that case being set for shore, as in model yacht sailing.



BARREL CARRYING WIRE LINE ASHORE. (From a sketch by Mr. C. W. Hunt.)

Mr. Harry Hughes Harrison sends us a suggestion of a life-saving torpedo. It would consist of two cigar-shaped bodies, joined by a steel framework, which also would support the motor and the two screws for propelling purposes. The motor would be driven from secondary batteries placed in the bottom body (which would float under water). The boat is to be controlled from the shore by a rope and steered electrically by a cable which it would drag after it. It would also carry a rope to which would be attached a breeches buoy. The sketch shows: A and B, the two bodies joined by frame work; C, D, rudder steered by the electric magnet, E; at F is an electro-motor driven by secondary cells at G; H H are two-bladed and three-bladed propellers on shaft I; J, electric light; K, dead eye to prevent rope from slipping through the pulleys; L, eyelet for the ship to catch and attach; M, breeches buoy; N, electric cable with four wires for steering; Y, control rope from shore; X, life line.

The idea is that the boat, having been launched, drags the two ropes—the controlling and the rescuing ropes—after it, and is guided to the ship. Having reached that, it would be possible for the people on board to catch hold of it by a boat hook or some other means.



A LIFE-SAVING TORPEDO. (From sketches by Mr. H. H. Harrison.)

* Continued from SUPPLEMENT, No. 861, page 13755.

H. M. S.S. RAMILLIES AND REPULSE.

OUR engraving, for which, together with the following particulars, we are indebted to the *Engineer*, will give an excellent idea of what the Ramillies and her sister ship the Repulse will be like when finished and at sea. They are both extremely powerful men-of-war; probably the most powerful in the world, not excepting the great Italian vessels. They are steel, twin screw, double-barbette battleships of 14,150 tons displacement, measuring 380 ft. long and 75 ft. broad, and having a mean draught of 27 ft. 6 in. The engines of the Repulse, which are vertical triple expansion, will develop 9,000 horse power with natural draught, and will drive the ship, it is expected, at a speed of 16 knots. With forced draught they will develop 13,000 horse power, and give a speed of 17·5 knots. The ship will carry 900 tons of coal, which will enable her to steam 5,000 knots at 10 knots an hour without refilling her bunkers; but, in case of necessity, she will be able to stow about 400 tons more, and so obtain an anticipated radius of over 7,000 knots.

The chief weights to be carried are the armament, 1,910 tons, and the armor, 4,550 tons. At each end there is a section, 65 ft. long, which is entirely without vertical armor, the only protection there being afforded by a 2½ in. steel deck. The whole middle section of the ship is furnished with a water line belt, of a maximum thickness of 18 in., 250 ft. long, and extending 5 ft. 6 in. below and 3 ft. above the line of load draught immersion. The ends of the belt are joined by transverse armored bulkheads, which rest upon the armored deck. At each end of the armored inclosure which is thus formed there rises to above the level of the upper deck a barbette composed of 17 in. armor. On the top of the armored belt rests a 3 in. steel deck, and above this, to a height of some feet, the outer walls of the ship are composed of 4 in. steel upon a 1 in. steel skin. Again, above this there is armor in the shape of steel shields to the larger broadside guns. Finally, there are two armored conning towers, one forward composed of 14 in. and one aft composed of 3 in. plates. Each barbette is a separate and very strong pear-shaped two-storied redoubt. In the upper story is the turntable carrying the guns; in the lower are the turning engines, etc., and as the whole structure is thickly armored all the way down to 5 ft. 6 in. below the water line, there is obviously little danger of a hostile shell putting the heavy guns out of action by exploding beneath them. The tops of the barbettes project but 2 ft. 9 in. above the upper deck. Consequently the axes of the guns are only about 4 ft. 6 in. above that deck.

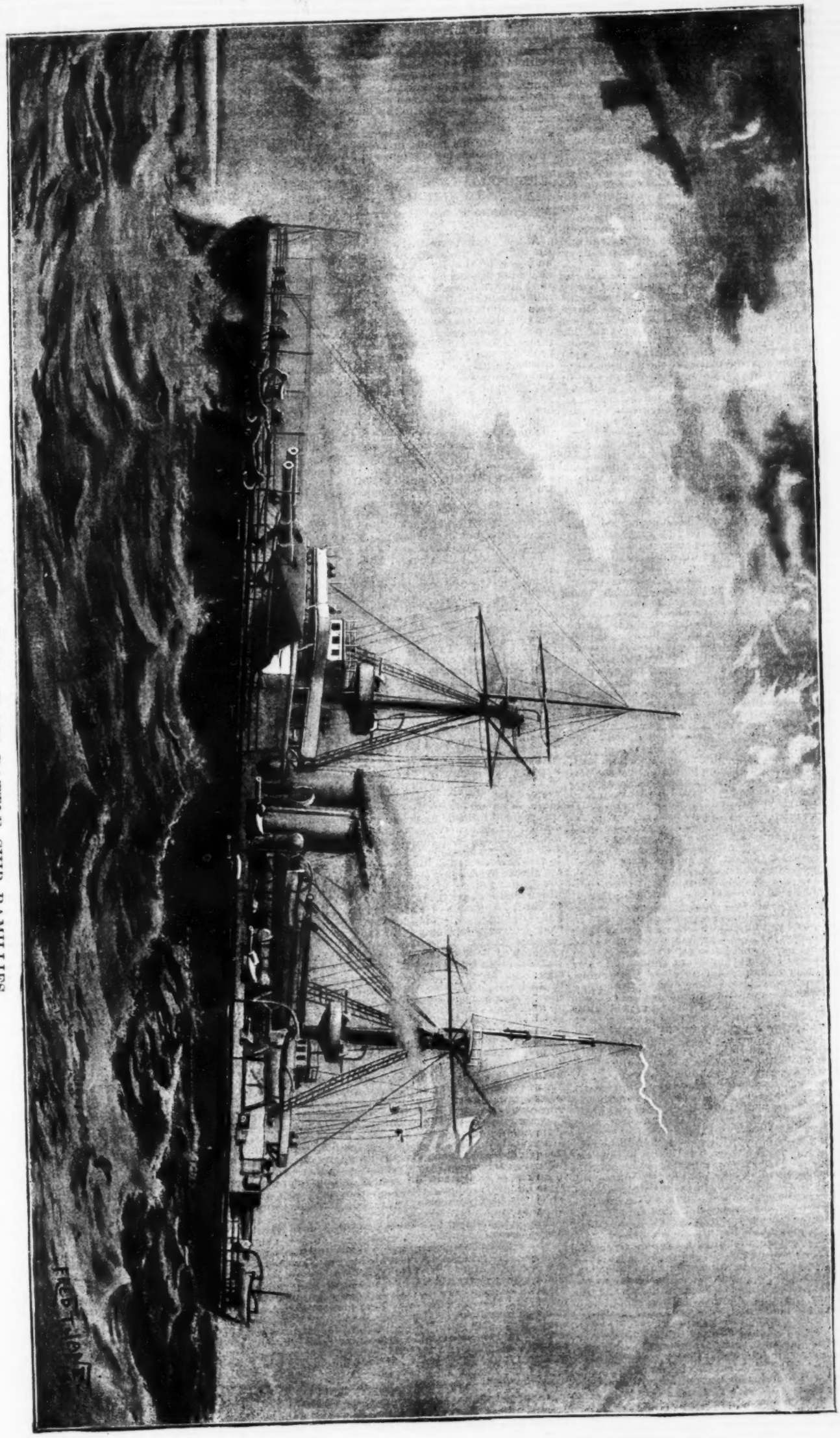
The freeboard of the Repulse and her sisters will be 18 ft., and the heavy guns themselves will be 23 ft. above the water, instead of 20 ft., as in the completed "Admirals." The chief armament of the Ramillies and Repulse will consist of four 13·5 in. 67 ton guns, disposed two in each barbette. These have arcs of training of about 200 deg., and all four guns can be simultaneously discharged on either broadside. The secondary armament will consist of ten 6 in. quick-firing guns of 40 calibers. These are carried in the box battery between the barbettes, two on each broadside being on the main deck in sponsons and three on each broadside being on the upper deck. The tertiary armament consists of sixteen 2·24 in. 6-pounder quick-firing guns, twelve of which are on the main and four on the upper deck; ten 1·85 in. 3-pounder quick-firing guns on the upper deck and superstructure, and in the tops; eight machine guns, and, for landing purposes, two 9-pounder field guns. There will also be five above-water and two submerged torpedo tubes. The total estimated cost is £831,678.

The Repulse will be supplied with engines by Messrs. Humphrys & Tennant. She was launched with great success at Pembroke, at a little after 5 P. M. on Feb. 27 last. The Ramillies will be engined by her builders. The cylinders will be 40 in.+59+80 in.×51 in. There will be eight boilers, single ended, working at 150 lb. pressure. She will carry a crew of 665 officers and men. Her construction did not commence until August, 1890; so she has only occupied eighteen months in building.

The launch of the Ramillies took place on March 1, and was attended by some sensational incidents. As the river is narrow for so huge a vessel, the ways were laid at a smaller incline than usual. The cold weather solidified the grease, and at 1 P. M., when the dog shores were knocked away, she refused to move. The greatest efforts was made with the hydraulics and the tugs in the river, and at last she started, at the rate of about an inch a minute. Every one went to luncheon, and the ship was left to the workmen. As a last resource the position of the tugs in the river was altered. Then, and not until then, did the rate of progress quicken, and at twenty minutes after three the Ramillies deliberately disappointed the prophets of evil and took the water, after having been in almost continuous motion for the period of one hour and twenty-six minutes. An hour later she was safely berthed alongside the yard.

PROFESSOR JAMES THOMSON.

PROF. JAMES THOMSON, who died on May 8, after a few days' illness, the result of a chill, was born in Belfast in 1822. He was the son of James Thomson, who was then lecturer on, and afterward professor of, mathematics in Belfast, and subsequently became Professor of Mathematics in Glasgow University. The father was a highly successful teacher and original investigator in mathematics, and was the author of many important school books. One of these books was, thirty years ago, still the recognized text book on arithmetic in Ireland, and in all probability still retains its position. It was referred to by its very well known title, the "Thomson," by Prof. Tyndall in his British Association address in 1874. We do not need the assurances of contemporaries, which are plentiful,



HER MAJESTY'S FIRST-CLASS BATTLE SHIP RAMILLIES.

that the two boys, James and William Thomson (now Lord Kelvin), made brilliant progress in their father's subject, and exhibited, even in early days, that combination of inventive genius and painstaking effort for accuracy which have been their great characteristics since. James took his M.A. degree at Glasgow, served an apprenticeship under Sir William Fairbairn, and practiced in Belfast as an engineer. He held the appointments of engineer to the Belfast Water Commissioners and to the Lagan Canal Navigation Works. In 1857 he became professor of civil engineering in Queen's College, Belfast, and his Belfast pupils are to be found occupying high positions in every part of the world. He succeeded Rankine in Glasgow in 1872, and resigned the professorship at Glasgow in 1889 because his eyesight was failing. He became a fellow of the Royal Society in 1877. He received the honorary degrees of D.Sc. from the Queen's University of Ireland and of LL.D. from Glasgow and from Dublin. In 1853 he married the only daughter of the late Mr. William John Hancock, J.P., of Lurgan, County Armagh, and it is a pathetic circumstance connected with his death that she and one of his daughters survived him only a few days. He leaves a son and another daughter.

In his private engineering practice at Belfast, he carried out important work in hydraulic machinery for use at home and in foreign countries. He invented the inward flow vortex turbine, and even now there are men in Ulster who are willing to talk at great length about his troubles and successes with this turbine. There was no practical man, however clever, who did not at first ridicule the scientific young gentleman who proposed to replace an eighty foot wheel by a tiny turbine, whose wheel was less than a foot in diameter. He never in his life could have had a happier moment than that in which, surrounded by crowds of astonished rustics and practical engineers, he saw this tiny wheel in its very first trial driving the machinery of a large mill. And now, wherever turbines are to be found all over the world, they are mostly "Thomson" turbines, made on the principles so clearly thought out and described by him, albeit they are known under many very different names. His notions on such subjects as strength of materials and the effect of initial strains in materials, although published forty-four years ago, have only lately become the notions of practical engineers. At that early date, his ideas on many of the applications of science in engineering were very clear and correct, and far in advance of his contemporaries. He is especially to be recognized for his services in practical hydrodynamics, a subject in which there has been a more misleading appearance of mathematical theory than in any other branch of engineering. To one of Thomson's pupils it is positively painful to take up any authoritative treatise on hydraulic machinery, for he knows that nearly every page of troublesome mathematical reasoning is based on some absurd assumption, and that James Thomson's few propositions are almost the only ones on which the engineer can rely. James Thomson seemed to fear the misuse by young engineers of the recognized mathematical methods of attacking physical problems. He, himself, when he used mathematical expressions, used them merely to put before others the results of his own method of reasoning. It expresses only a part of the truth to say he thought about things geometrically rather than algebraically. He refrained from publication until his proof was perfect, and some of his pupils may feel sorry that they have not more faithfully followed their master's example. A study of his successive manuscript proofs of his law of flow of fluids from similar orifices would probably enable us to conceive of the habits of thought of the Greek geometers; every word and phrase is carefully selected, and considered time after time with a view to perfect accuracy. Such invention and such regard for perfection of detail were surely never combined before.

When any of his speculations has been once published in an authoritative text book, it will be noticed that it appears in all text books published subsequently; the melting point of ice, the triple point in water stuff, the continuity in the steam water isothermal, the tears of strong wine, are a few examples. No doubt, as time goes on, text book writers will find that he discovered other important things. He was such a very observant man that he often put forward his most important propositions when explaining phenomena that seemed utterly insignificant. Let the reader only think that what occurs in a wash basin, or in a little rivulet near the sea, may be of great importance scientifically, and let him read again some of Thomson's insignificant-looking scattered papers, and he will find important propositions published which will not, perhaps, for some years yet, find their proper positions in the text books.

Of the history of thermodynamics during the eventful years 1849-50, who dares now to say anything? Nor can any one now say anything about the great glacier dispute. One thing is certain, however, that James Thomson's discovery of the necessary lowering of the melting point of ice with pressure, published on January 2, 1849, settled forever the theory of the flow of glaciers. Joule's work was beginning to be known, but Thomson in his proof, like Lord Kelvin in the well known paper published on the same day, adopts Carnot's idea of the conservation of heat. A change in one expression, not essential to the proof itself, was all that was needed after the first and second laws of thermodynamics had been recognized. Of his various papers on hydrodynamics, capillarity, heat, light, and the states of matter, published since that time, we have not space to say more than that each of them made a substantial addition to our knowledge. His latest work, the Bakerian lecture this year of the Royal Society, on "The Grand Currents of Atmospheric Circulation," is such a paper as we might expect from a man who had given more than thirty-five years of study to the subject, that subject being one which was peculiarly his own. It is possible that the practical engineer, judging from the title merely, may neglect to read a paper which is one of phenomenal importance to the engineer as well as to the physiographer.

He was a man of singular purity of mind and simplicity of character, very clear sighted in all that pertained to moral right and wrong, and conscientious to a degree. In his presence one felt in a purer atmosphere, where mean things seemed impossible. No professor was ever so willing to take trouble (not mere momentary trouble, but trouble of days and nights) in the interests of a student, but no professor was ever so rigidly exact in giving certificates and testimonials. The present writer has talked often with his old pupils about him, but never met one of them who, besides a great respect, had not also a genuine and kindly and pleasurable love for his old professor, whose kindness and patience had been unfailing, and whose sympathy had many a time been extended to him. How useless it is to speak of the good done to the world by a man of his character. Every one of his pupils, in however small or great a degree, is extending the range of his influence.

MICRO-ORGANISMS IN THEIR RELATION TO CHEMICAL CHANGE.*

By Professor PERCY F. FRANKLAND, Ph.D., B.Sc., F.R.S.

ALMOST exactly on this day twenty-two years ago the subject of micro-organisms was introduced to the audience of the Royal Institution in one of those charming discourses which so many of us well know were always to be heard from Dr. Tyndall. The title of his discourse on that occasion was "Dust and Disease," and its contents should be studied by all interested in this department of science, forming as it does a part of the classical literature of the subject in which it marks the commencement of a new epoch. It has probably rarely, if ever, happened before, that in so short a period as twenty-two years any science has undergone such a marvelous advance as that which has taken place in the case of bacteriology, the science which is devoted to the study of those low forms of life which we group together under the name of *micro-organisms*. This advance has been made through the ungrudging expenditure of self-denying labor by a great body of earnest workers of nearly every nationality. The subject is indeed one calculated to draw forth interest and enthusiasm, for the problems involved are not only of high scientific importance, but are also of incalculable moment to mankind, and indeed to the entire living creation. The great impetus which this new science received at its outset was imparted by Pasteur, who has not only laid the foundations, but also added, and is still adding, so much to the superstructure of its many mansions.

The side of bacteriology with which the general public is most commonly brought in contact is that which relates to disease, but of this I propose saying absolutely nothing to-night. It has been dealt with by others in this place, and notably by my friend Dr. Klein. There is a second side of bacteriology, which has also a special interest for at least a portion of the public in consequence of the invaluable assistance which it has afforded to some sections of the industrial world. Indeed, chronologically, this industrial department of bacteriology was the first which claimed attention, for the growers of wine, the brewers of beer, and the manufacturers of fermented liquors of all kinds from the highest antiquity have been practical bacteriologists, of the same spontaneous order, it is true, as M. Jourdain was an unconscious author of prose.

It was Pasteur also who first infused science into the operations of the wine vat and the fermenting tun, by his classical "Etudes sur la Bière et sur le Vin." It was he who first showed that the normal work of the brewery was accomplished by particular forms of micro-organisms, known as yeast, and that the frequent failures to produce beer or wine of the desired quality were occasioned by the presence of foreign forms of micro-organisms giving rise to acidity and other undesirable changes in these beverages. In these researches of Pasteur's on beer and wine, we are almost for the first time brought face to face with the precise nature of some of the chemical changes which micro-organisms bring about. The time-honored vinous fermentation of sugar, the products of which had been valued and indulged in by man even from the days of Noah, is for the first time so accurately studied as to be definable almost with the precision of a chemical equation. Similar attention was also given by Pasteur to some of the other micro-organisms which deteriorate the quality of the beer, thus more especially to the bacterium which causes the *acetic* or vinegar fermentation, which is a process of *oxidation*, transforming alcohol into vinegar; to the bacillus inducing the *lactic* fermentation, which is a process of *decomposition*, in which sugar yields lactic acid; as well as to that which brings about the *butyric* fermentation, a process of *reduction* in which butyric acid is formed. These are the foundations and scaffolding on which subsequent investigators of the phenomena of fermentation have labored. Thus making use of more refined methods than those which were at the disposal of Pasteur, Christian Hansen, of Copenhagen, has enormously extended our knowledge of the alcohol-producing organisms or yeasts; he has shown that there are a number of distinct forms, differing indeed but little among themselves in shape, bnt possessing very distinct properties, more especially in respect of the nature of certain minute quantities of secondary products to which they give rise, and which are highly important as giving particular characters to the beers produced.

Hansen has shown how these various kinds of yeast may be grown or cultivated in a state of purity even on the industrial scale, and has in this manner revolutionized the practice of brewing on the Continent. For during the past few years these pure yeasts, each endowed with particular properties, have been grown with scrupulous care in laboratories equipped expressly for this purpose, and these pure growths are thence dispatched to breweries in all parts of the world, particular yeasts being provided for the production of particular varieties of beer. In this manner scientific accuracy and the certainty of success are introduced into an industry in which before much was a matter of chance, and in which nearly everything was subordinated to tradition and blind empiricism.

THE BACTERIA CONNECTED WITH THE SOIL.

It is, however, with regard to the bacteria connected with other industries than those of alcoholic fermentation that our knowledge has particularly advanced during the last few years. Thus some of the most important phenomena in agriculture have recently received a most remarkable elucidation through the study of bacteria. Scientific agriculturists are generally agreed that one of the most important plant foods in a soil is *nitric acid;* indeed, they inform us that if the soil were utterly destitute of this material, it would be incapable of growing the barest pretense of a crop, *either of corn, or of roots, or of grass*, even if the soil were in other respects of the most superb texture, however favorably it might be situated, however well drained, tilled, and supplied with the purely mineral ingredients of plant food, such as *potash*, *lime* and *phosphoric acid*. Yet, notwithstanding the commanding importance of this substance nitric acid to vegetation, it is present in ordinary fertile soils in but little more than homeopathic doses.

These facts are gathered from those grand experiments which have during the past half century been going on at Rothamsted under the direction of Sir John Lawes and Dr. Gilbert and which have rendered the Hertfordshire farm a luminous center of the whole agricultural world. From these experiments it appears that sometimes there is in fertile soil under 1 part, and often under 10 parts, of nitrate of lime per million of soil. Now the cause of such minute quantities only of nitric acid being found in soils is due partly to this material being washed away by the rain and partly to its being so eagerly taken up by plants for the purposes of nutrition; for it has long been known that by suitable means the quantity can be enormously increased if no vegetation is maintained, and the ground properly protected from rain. The soil in fact, under ordinary circumstances, continuously generates this nitric acid from the various nitrogenous manures which are applied to it, and it is in the form of nitric acid that the nitrogen of manures principally gains access as nutriment to the plant.

It was in the year 1877 that two French chemists, Schloesing and Muntz, showed that this power of soils to convert the nitrogen of nitrogenous substances into nitric acid was due to low forms of life—to micro-organisms or bacteria. The proof which they furnished of this statement was of a very simple character, and consisted essentially in demonstrating that this production of nitric acid, or process of *nitrification*, as it is generally called, is promptly inhibited or brought to a standstill by all those materials which have the property of destroying micro-organisms, and which we called *antiseptics*, while similarly the process is stopped by heat and other influences which are known to be fatal to life in general. These results of Schloesing and Muntz were confirmed and greatly extended in this country by Mr. Warington and Dr. Munro; but, although the vital nature of the process was fully established, little practical advance was until recently made in the identification or isolation of the particular bacteria responsible for this remarkable and invaluable transformation. In 1886, however, a very important step was made by Dr. Munro, who showed that this process of nitrification could take place in solutions practically destitute of organic matter, or, in other words, that the vital activity of the bacteria of nitrification could be maintained without nutriment of an organic nature. In 1885, I had myself established the fact that some micro-organisms can actually undergo enormous multiplication in ordinary distilled water:

MULTIPLICATION OF MICRO-ORGANISMS IN DISTILLED WATER.*

Hours after Introduction of Micro-organisms.	Number of Micro-organisms found in 1 c. c. of Water.
0	1,073
6	6,028
24	7,262
48	48,100

In taking up the subject of nitrification in conjunction with my wife in the autumn of 1886, I determined to avail myself of this remarkable property of the nitrifying organisms to grow in the absence of organic matter, thinking that in this way it would be possible to achieve a separation of the nitrifying organisms from other forms which can only grow if organic food materials are supplied to them. Proceeding on these lines, we have carried on the process of nitrification over a period of upward of four years without the nitrifying organisms being supplied with any organic food materials whatsoever.

COMPOSITION OF SOLUTION EMPLOYED FOR NITRIFICATION.

Ammonium chloride	0·5 grm.	In 1,000 c. c. of distilled water.
Potassium phosphate	0·1 "	
Magnesium sulphate	0·02 "	
Calcium chloride	0·01 "	
Calcium carbonate	5·0 "	

In a solution of this composition the process of nitrification was carried on over a period of upward of four years. In carrying on this series of experiments it was soon evident that although a number of forms foreign to the nitrification process were being eliminated, there were still some remaining alongside of the nitrifying organisms, or, in other words, that a pure culture of the nitrifying organisms had not been obtained. From various considerations, however, we came to the conclusion that the nitrifying organisms probably differed from the other forms which were still present along with them, in being unable to grow on the common cultivating medium employed by bacteriologists, and known as gelatin-peptone. The separation from these foreign forms was ultimately effected by enormously diluting one of these nitrifying solutions, and then taking out small portions of this diluted material and introducing each of these portions into separate ammoniacal solutions. In some of these nitrification was established, in others not; while among those in which nitrification *was* established, some contained organisms which grew upon gelatin, while one refused to give any growth on the gelatin at all, although it was seen under the microscope to contain abundantly bacteria of the form shown in the diagram.

These results, which were published in March, 1890, were followed in about a month by a communication in the *Annales de l'Institut Pasteur*, by W. Wino-

* A recent lecture at the Royal Institution.

* Proc. Roy. Soc., 1885.

gradsky, who had also separated a very similar, if not identical, nitrifying organism, and a few months later again a similar separation was made by Mr. Warington. But these discoveries had not completely unraveled the problem of nitrification, for the organisms separated in these three independent investigations possessed only the property of *converting ammonia into nitrous and not into nitric acid.* The nitrous acid is an intermediate body, which, curiously, is rarely found excepting in very minute quantities in soil. The changes will be more clearly understood by reference to the chemical equations:

(1) $NH_3 + 3O = H_2O + NHO_3$
Ammonia. Oxygen. Water. Nitrous acid.

(2) $NHO_2 + O = NHO_3$
Nitrous acid. Nitric acid.

The organisms separated by Winogradsky, by Warington and by myself, possessed only the property of effecting the first of these changes, they were absolutely destitute of the power of bringing about the second. Now, the curious thing is that the first of these changes is by far the most difficult to accomplish by *purely chemical means*, while the second can be brought about with the greatest facility. In order to bring about the first change, we have to employ one of the most powerful oxidizing agents known to chemists, viz., ozone. We thus see that the power of oxidation, possessed by our nitrifying organism, is altogether unique, and does not find its parallel among purely chemical agents of oxidation. *But how, then, is the nitric acid found in the soil produced, when these organisms yield only nitrous acid?*

At the time when I found that the organism which I had separated produced nitrous acid exclusively, I pointed out that it was doubtless explicable on one of two hypotheses: (1) that nitrous and nitric acids are produced by totally distinct organisms; or (2) that the same organism produces the one or the other, according to the conditions under which it is growing. More recent researches of Winogradsky have shown that the first of these two alternative hypotheses is the correct one, for by making cultivations of soil in a solution containing nitrous acids and no ammonia, Winogradsky has succeeded in isolating a micro-organism which possesses the power of converting nitrous acid into nitric acid, but has no power of attacking ammonia. This second organism, or *nitric ferment*, as we may call it, resembles in its activity the purely chemical oxidizing agent—*potassium permanganate*—which has no action on ammonia, but readily converts nitrous into nitric acid. The process of nitrification in the soil now becomes intelligible in its entirety. It is the work of two independent organisms, the first of which converts ammonia into nitrous acid, while the second transforms into nitric acid the nitrous acid produced by the first.

There is a point in connection with the distribution of nitric acid in nature which is exceedingly remarkable, and which forces itself upon the attention of every student of the process of nitrification. Although nitric acid is generally so scantily present in the soil, there is one notable exception to this rule, for in the rainless districts of Chile and Peru there are found immense deposits of nitrate of soda, or Chile saltpeter, as it is called, which would appear to represent the result of a gigantic nitrification process in some previous period of the earth's history. The vast quantities of this material which occur in these regions of South America can be gathered from the fact that its exportation has for years been going on at the rate indicated by the following figures: During the first six months of 1890 there were brought to the United Kingdom 90,000 tons and to the European Continent 480,000 tons. From the presence of such altogether enormous quantities, one is almost tempted to hazard the suggestion that in this particular region of the earth, under some special circumstances of which we know nothing, the nitrifying organisms must have been endowed then and there with very much greater powers than they possess to-day, and it is particularly noteworthy that in a recent examination of soils from nearly all parts of the earth, one coming from Quito, and therefore not far distant from these nitrate fields, was found to possess the power of nitrification in a degree far beyond that exhibited by any other soil hitherto experimented with. Is it not possible, perhaps, that we have in these vigorous nitrifying organisms of the soil of Quito the not altogether unworthy descendants of that Cyclopean race of nitrifying bacteria which must have built up the nitrate wealth of Chile and Peru, and thus countless ages ago founded the fortunes of our nitrate kings of to-day?

But these nitrifying organisms have also assisted in teaching us a highly important lesson in connection with the maintenance of life. The facts which I have already referred to concerning the multiplication of micro-organisms in distilled water, and the continuation of the nitrification process over a period of four years in purely mineral solutions, are strong presumptive evidence in favor of these bacteria being able to gain a livelihood in the entire absence of organic foodstuffs. I refrained, however, from promulgating such a revolutionary doctrine until I should have had an opportunity of repeating these experiments with materials in which the absence of even the merest traces of organic matter had been assured, for, as chemists well know, even distilled water may contain traces of organic matter. Such a rigid proof as I had contemplated has, however, in the meantime been attempted by M. Winogradsky, also in connection with his experiments on nitrification, and he has indeed found that the nitrifying organisms flourish, multiply, and actually build up living protoplasm in a solution from which organic matter has been most rigorously excluded. Now this living protoplasm in the experiments in question must have been elaborated by these bacteria from carbonic acid as the source of the protoplasmic carbon, and from ammonia and nitrous or nitric acids as the source of the protoplasmic nitrogen. If these experiments are correct, and they were undoubtedly performed with great skill and much caution, they are subversive of one of the fundamental principles of vegetable physiology, which denies to all living structures, save those of green plants alone, the power of building up protoplasm from such simple materials.

I had occasion to mention in connection with these nitrifying organisms that they refuse to grow on the ordinary solid cultivating media employed by bacteriologists, a fact which presents a great obstacle to their isolation in a state of purity, for it is just by means of these solid culture media that micro-organisms are most easily obtained in the pure state. This difficulty has, however, been overcome in a most ingenious manner, originally devised by Prof. Kuhne, in which the solid medium is wholly composed of mineral ingredients, the jelly-like consistency being obtained by means of silica.

FIXATION OF FREE NITROGEN BY PLANTS.

But while the study of the bacteria giving rise to nitrification has thus led to the subversion of what was regarded as a firmly established principle of vegetable physiology (*viz., the incapacity of any but green plants to utilize carbonic acid in the elaboration of protoplasm*), the same science has received another shock of perhaps equal if not greater violence through researches which have been carried on with other micro-organisms flourishing in the soil. For nearly a century past agricultural chemists and vegetable physiologists have been debating as to whether the free nitrogen of our atmosphere can be assimilated or utilized as food by plants. This question was answered in the negative by Boussingault about fifty years since; the problem was again attacked by Lawes, Gilbert and Pugh about thirty years ago, and *their* answer was also in the negative. In the course, however, of their continuous experiments on crops, Lawes and Gilbert have frequently pointed out that while the nitrogen in most crops can be accounted for by the combined nitrogen supplied to the land in the form of manures and in rain water, yet in particular *leguminous* crops, such as peas, beans, vetches and the like, there is an excess of nitrogen which cannot be accounted for as being derived from these obvious sources. The origin of this excess of nitrogen in these particular crops they admitted could not be explained by any of the orthodox canons of the vegetable physiology of the time. The whole question of the fixation of atmospheric nitrogen by plants was again raised in 1876 by a very radical philosopher, in the person of M. Berthelot, while the most conclusive experiments were made on this subject by two German investigators, Prof. Hellriegel and Dr. Wilfarth, who have not only shown that this excess of nitrogen in leguminous crops is obtained from the atmosphere, but also that this assimilation of free nitrogen is dependent upon the presence of certain bacteria flourishing in and around the roots of these plants, for when these same plants are cultivated in sterile soil, the fixation of atmospheric nitrogen does not take place. Moreover, the presence of these microbes in the soil occasions the formation of peculiar swellings or tuberosities on the roots of these plants; and these tuberosities, which are not formed in sterile soil, are found to be remarkably rich in nitrogen, and swarming with bacteria.

Extremely important and instructive in this respect are the experiments of Professor Nobbe, who has not only confirmed the results mentioned, but has endeavored to investigate the particular bacteria which bring about these important changes, and he has indeed succeeded in showing that in many cases each particular leguminous plant is provided with its particular micro-organism, which leads to its fixation of free nitrogen. Thus he found that if pure cultivations of the bacteria, obtained from a pea tubercle, were applied to a pea plant, there was a more abundant fixation of atmospheric nitrogen by this pea plant than if it was supplied with pure cultures of the microbes from the tubercles of a lupin or a robinia. While similarly the robinia was more beneficially affected by the application of pure cultures from robinia tubercles than by those from either pea tubercles or lupin tubercles. This subject of the source of nitrogen in leguminous plants has again been taken up by Sir John Lawes and Dr. Gilbert at Rothamsted, and their recent results fully confirm the observations of these foreign investigators that it is partially derived from the free atmospheric nitrogen through the agency of bacteria in the soil. To micro-organisms again, then, we must ascribe the accomplishment of this highly important chemical change going on in the soil, although it has not hitherto been so fully illuminated as the process of nitrification.

SELECTIVE ACTION OF MICRO-ORGANISMS.

Any of the ordinary plants and animals with which we are familiar may be regarded as analytical machines; and we ourselves without any knowledge of chemistry, are constantly performing analytical tests. Thus, we can all distinguish between sugar and salt by the taste, between ammonia and vinegar by the smell; while by a more elaborate investigation we distinguish, for instance, between the milk supplied from two different dairies, by ascertaining on which we or our children thrive best. In fact, such analytical or selective operations are among the first vital phenomena exhibited by an organism on coming into this world. It is, however, particularly surprising to find this analytic or distinguishing capacity developed in an extraordinarily high degree among micro-organisms. From the power which we have seen that some possess of flourishing on the extremely thin diet to be found in distilled water, we should be rather disposed to think that caprice would be the very last failing with which they would be chargeable. As a matter of fact, however, the perfectly unfathomable and inscrutable caprice of these minute creatures is among the first things with which the student of bacteriological phenomena becomes impressed. Let me call your attention to a striking example of this, which I have recently investigated.

I have here two substances, which have the greatest similarity:

	Mannite.	Dulcite.
Occurrence.	Numerous plant juices.....	Ditto, but less frequently.
Taste.	Sweet.....	Ditto, but less so.
Melts.	166° C.....	188° C.
Crystalline form.	Large rhombic prisms....	Large monoclinic prisms.

Not only, however, do these two substances possess such a strong external resemblance to each other, but in their chemical behavior also they are so closely allied that one formula has to do duty for both of them, for so slight is the difference in the manner in which their component atoms are arranged that chemists have not yet been able with certainty to ascertain in what that difference consists. Under these circumstances it would have been anticipated that bacteria would be quite indifferent as to which of these two substances was presented to them, and that they would regard either both or neither as acceptable. But such is by no means the case; some micro-organisms, like ordinary yeast, have *no action upon either*, while *others will attack mannite, leaving dulcite untouched, others again being less discriminating, attack both*; representatives of a fourth possible class *which would act upon dulcite but not upon mannite* are as yet undiscovered. The *Bacillus ethaceticus*, I have recently shown, has the property of breaking down the mannite molecule into alcohol, acetic acid, carbonic anhydride and hydrogen, but leaves the dulcite molecule untouched. More recently I have, in conjunction with my late assistant, Mr. Frew, succeeded in obtaining a micro-organism (*B. ethacetosuccinicus*) which decomposes both mannite and dulcite into alcohol, acetic and succinic acids, carbonic anhydride, and hydrogen.

OPTICALLY ACTIVE SUBSTANCES.

But these are by no means the ultimate limits to which the selective or discriminating powers of micro-organisms can be pushed, for although mannite and dulcite are extremely similar substances, they are not chemically identical. We are acquainted, however, with substances which, though chemically identical, are different in respect of certain physical properties, and are hence known as *physical isomers.* It is in explanation of this physical isomerism that one of the most beautiful of chemical theories was propounded by Lebel and Van't Hoff in 1874, and which remains unsupplanted to the present day. This theory depends upon taking into consideration the dissymmetry of the molecule which is occasioned by the presence in it of a carbon atom which is combined with four different atoms or groups of atoms, and is most easily intelligible from an inspection of these two models. This molecular dissymmetry is specially exhibited in the crystalline form of such substances, and in their action upon polarized light. The molecule arranged according to the one pattern has the property of turning the plane of polarization in one direction, while the molecule arranged according to the other pattern has invariably the property of turning the plane through precisely the same angle in the opposite direction. The molecular dissymmetry ceases when two such molecules combine together, the resulting molecule having no action on polarized light at all. The interest of these phenomena in connection with micro-organisms lies in the fact that they are sometimes possessed of the power of discriminating between these physical isomers. Although this remarkable property was demonstrated years ago by Pasteur in respect of the tartaric acids, it has only comparatively rarely been taken advantage of. Recently, however, chemical science has been enriched in several instances by successfully directing the energies of micro-organisms in such work of discrimination.

During the past few years no chemical researches have commanded more interest, both on account of their theoretic importance and the fertility of resource exhibited in their execution, than those of Emil Fischer, which have led to the artificial preparation in the laboratory of several of the various forms of sugar occurring in nature, as well as of other sugars not hitherto discovered among the products of the animal or vegetable kingdoms. The natural sugars are all of them bodies with dissymmetric molecules, powerfully affecting the beam of polarized light, but when prepared artificially they are without action on polarized light, because in the artificial product the left-handed and right-handed molecules are present in equal numbers, the molecules of the one neutralizing the molecules of the other, and thus giving rise to a mixture which does not affect the polarized beam either way. By the action of micro-organisms, however, on such an inactive mixture, the one set of molecules is searched out by the microbes and decomposed, leaving the other set of molecules untouched, and the latter now exhibit their specific action on polarized light, an active sugar being thus obtained.

The most suitable micro-organisms to let loose, so to speak, on such an inactive mixture of sugar molecules are those of brewers' yeast, which decompose the sugar molecules with formation of alcohol and carbonic anhydride. Their action on these inactive artificial sugars of Fischer's is particularly noteworthy. One of the principal artificial sugars prepared by Fischer is called *fructose.* It is inactive, but consists of an equal number of molecules of oppositely active sugars called *lævulose.* One set of these lævulose molecules turns the plane of polarization to the right, and we may call them *right-handed lævulose*, while the other set of *lævulose molecules* turns the plane of polarization to the left, and we may call them *left-handed lævulose.* The left-handed lævulose occurs in nature, while the right-handed lævulose, as far as we know, does not. Now, on putting brewers' yeast into a solution of the fructose, the yeast organisms attack the left-handed lævulose molecules and convert them into alcohol and carbonic anhydride, while the right-handed lævulose is left undisturbed. The yeast organisms thus attack that particular form of lævulose of which their ancestors can have had experience in the past, while they leave untouched the right-handed lævulose molecules, which, being a new creation of the laboratory, they have no hereditary instinct or capacity to deal with. This selective power is possessed also by other forms of micro-organisms besides the yeasts, which are indeed only suitable for the separatory decomposition of sugars, and by means of bacterial forms a much greater variety of substances can be attacked in this manner. Thus I have recently found that glyceric acid can be decomposed by the *B. ethaceticus*, to which I have already referred this evening. This glyceric acid is thus represented by chemists:

$$C_3H_6O_4 \quad \text{or} \quad \begin{matrix} (CH_2OH) \\ | \\ (H)—C\ OH) \\ | \\ (COOH) \end{matrix}$$

and this should, according to Lebel and Van't Hoff's theory, be capable of existing in two physically isomeric forms, as easily shown by our models. The ordinary glyceric acid known to chemists is, however, quite inactive to polarized light, and must consist, therefore,

of a combination in equal molecules of a right-handed and left-handed glyceric acid. Now when the *B. ethaceticus* is put into a suitable solution of the calcium salt of this glyceric acid, it multiplies abundantly and completely consumes the right-handed molecules of the salt, but leaves the left-handed molecules entirely intact, a powerfully active glyceric acid being thus obtained.

A number of derivatives of this new active glyceric acid have recently been prepared in my laboratory :

DERIVATIVES OF ACTIVE GLYCERIC ACID.

Formula.	Specific Rotation. $[\alpha]_D$
$(C_3H_5O_4)_2Ba + 2H_2O$	− 9°
$(C_3H_5O_4)_2Sr + 3H_2O$	− 10°
$(C_3H_5O_4)_2Ca + 2H_2O$	− 12°
	$[\alpha]$
$(C_3H_5O_4)_2Cd + 1½H_2O$	− 14°
$(C_3H_5O_4)_2Zn + H_2O$	− 22°
$(C_3H_5O_4)_2Mg + H_2O$	− 18·5°
$C_3H_5O_4Na$	− 16°
$C_3H_5O_4Am$	− 20°
$C_3H_5O_4K$	− 15°
$C_3H_5O_4Li$	− 20·5°
$C_3H_5O_4Me$	− 4·8°
$C_3H_5O_4Et$	− 9·2°
$C_3H_5O_4Pr$ (*n*)	− 13·0°

Here again then chemistry has been enriched by a number of new compounds, which we owe entirely to the unaccountable caprice of this micro-organism.

INDIVIDUALITY OF MICRO-ORGANISMS.

Although micro-organisms are thus becoming more and more indispensable reagents in the chemical laboratory, essential as they are for the production of many bodies, it is always necessary to bear in mind that by virtue of their vitality their nature is infinitely more complex than that of any inanimate chemicals which we are accustomed to employ. In a chemically pure substance we believe that one molecule is just like another, and hence we expect perfect uniformity of behavior in the molecules of such a pure substance under prescribed conditions. In a pure cultivation of a particular species of a micro-organism, however, we must not expect such rigid uniformity of behavior from each of the individual organisms making up such a cultivation, for there may be and frequently are great differences among them; in fact, each member of such a pure culture is endowed with a more or less marked individuality of its own, and these possible variations have to be taken into consideration by those who wish to turn their energies to account. In fact, experimenting with micro-organisms partakes rather of the nature of legislating for a community than of directing the inanimate energies of chemical molecules. Thus frequently the past history of a group of micro-organisms has to be taken into account in dealing with them, for their tendencies may have become greatly modified by the experiences of their ancestors. Of this I will give you an instance which has recently come under my observation: Here is a bacillus which has the property of fermenting calcium citrate. I have found that it can go on exerting this power for years. On submitting this fermenting liquid to plate cultivation, we obtain the appearances which you see here. If one of these colonies be transferred to a sterile solution of calcium citrate, it invariably fails to set up a fermentation of the latter, the bacillus having thus by mere passage through the gelatin medium lost its power to produce this effect. If, however, we take another similar colony and put it into a solution of broth containing calcium citrate, fermentation takes place; on now inoculating from this to a weaker solution of broth containing calcium citrate, this also is put into fermentation, and by proceeding in this manner we may ultimately set up fermentation in a calcium citrate solution which absolutely refused to be fermented when the bacilli were taken directly from the gelatin plate.

Phenomena of this kind clearly indicate that there may be around us numerous forms of micro-organisms of the potentiality of which we are still quite ignorant; thus if we were only acquainted with the bacilli I have just referred to from gelatin cultures, we should be quite unaware of their power to excite this fermentation of calcium citrate, which we have only been enabled to bring about by pursuing the complicated system of cultivation I have indicated. It is surely exceedingly probable, therefore, that many of the micro-organisms with which we are already acquainted may be possessed of numerous important properties which are lying dormant until brought into activity by suitable cultivation. This power of modifying the characters of bacteria by cultivation is, I venture to think, of the highest importance in connection with the problems of evolution, for in these lowly forms of life, in which, under favorable circumstances, generation succeeds generation in a period of as little as twenty minutes, it should be possible through the agency of selection to effect metamorphoses, both of morphology and physiology, which would take ages in the case of more highly organized beings to bring about. We hear much about the possibility of altering the human race through training from the enthusiastic apostles of education, but even the most sanguine cannot promise that any striking changes will be effected within several generations, so that such predictions cannot be tested until long after these reformers have passed away. In the case of micro-organisms, however, we can study the effect of educational systems consequentially pursued through thousands of generations within even that short span of life which is allotted to us here.

REPORT ON PHOSPHORIC ACID.*

By W. B. BURNEY.

ADOPTING the usual method of reporting on phosphoric acid, the subject will be presented in the following order: (1) Condensed abstracts of methods published during the year; (2) results of work done by members of the association and others; (3) recommendations for the next year.

* From the *Proceedings* of the Seventh Annual Convention of the Association of Official Agricultural Chemists, Washington.

ABSTRACTS.*

The Estimation of Phosphoric Acid by Ammonium Molybdate.†

For the titration of phosphoric acid by molybdate, the latter should be acidified with three to four molecular proportions of nitric acid to one of molybdic acid, while the phosphate solution is only slightly acidified. Under these conditions one molecular proportion of phosphoric anhydride is exactly precipitated by twenty-four of MoO_3. Ten grammes of molybdic acid (or 12·362 grammes of crystallized hexammonium heptamolybdate) is dissolved in an excess of dilute ammonia, the solution neutralized, further acidified with 15 grammes nitric acid, and diluted to 1 liter. 24·3 to 24·5 c. c. precipitate 0·01 gramme P_2O_5.

For gravimetric determinations the author considers Finkener's method the best. The washed precipitate is dissolved in warm dilute ammonia, the solution evaporated until most of the ammonia is expelled, then mixed with an excess of nitric acid, evaporated, and heated to complete decomposition of the ammonium nitrate, the final temperature being about 180°. The residue contains 3·753 per cent. P_2O_5.

If the precipitate has been washed with neutral ammonium nitrate, it may be titrated as follows: It is stirred up with cold water containing phenolphthalein, and mixed with standard soda until it has completely dissolved and the liquid is red. It is then rapidly titrated back with nitric acid. One c. c. N / 10 soda = 0·00061739 gramme P_2O_5.

Analysis of Concentrated Superphosphates.‡

This superphosphate generally has from 4 to 5 per cent. of P_2O_5 as ferric or aluminic phosphate, which is insoluble in water, but soluble in concentrated solutions of superphosphate. It is therefore important to use sufficient water in the first extraction, otherwise the soluble P_2O_5 will be reported too high. Take 1·5 grammes of the superphosphate, place in a beaker, and add a little water to soften and break up the lumps. Then make up to 90 c. c. Allow it to stand five minutes, and filter off the supernatant liquid. To the residue add 90 c. c. of water, stir, allow it to settle, and filter. Treat the residue with 60 c. c. of water, warm gently, bring upon the filter, and wash once with hot water.

Citrate Method, Phosphoric Acid Determination.§

The author supposes that the double phosphates with ammonium form soluble compounds with ammonium citrate, and that only the magnesium ammonium phosphate is easily, but never completely, decomposed. To make this as complete as possible, more magnesium chloride than can combine with the ammonium citrate to form $MgNH_4C_6H_5O_7$ should be present, so that this excess may act upon the compound :

$$MgNH_4PO_4 + (NH_4)_3C_6H_5O_7,$$

which may have formed. Some $MgNH_4PO_4$, however, always remains in solution and causes a loss. When other bases (CaO, Fe_2O_3, Al_2O_3, MnO, FeO) are present, their phosphates are somewhat thrown down, and cause an error. With CaO the error is largest. If the lime has been removed by oxalate or sulphuric acid, a loss of P_2O_5 may always be expected if we do not use at least twice the amount of magnesia mixture usually prescribed. Silica always contaminates the precipitate when present. The author considers the molybdenum method more accurate.

In addition to the above article the author notes the following :‖

1. Treatment of the substance with hydrochloric acid is objectionable, as the precipitate may contain considerable silica.
2. Treatment with sulphuric acid reduces this error to about 1 mgrm. of silica.
3. Even when an excess of ammonium citrate is present and only little CaO, the precipitate contains from 1 to 2 mgrm. CaO as pyrophosphate.
4. The presence of manganese exerts a similar influence.
5. The error caused by Fe_2O_3 and Al_2O_3 in a sulphuric acid solution is very slight when little silica is present, even when large amounts of these oxides are present; they delay precipitation, however.
6. Small quantities of $Mg(OH)_2$ are always present; this error is slightest when the separation is made in a solution containing 2·5 per cent. ammonia. In a nearly neutral solution, and in the presence of alkaline salts, the error is greatest.
7. The phosphoric acid is always incompletely precipitated.
8. In making a control analysis by the molybdate method, the method of treating substances rich in silica must be regarded.

The average error, according to the author, is ± 0·128 per cent., the — result where only small quantities of P_2O_5 are present.

With Thomas slags and raw phosphates the results are always too high.

The Use of Phosphoric Acid of Animal or Mineral Origin in the Cultivation of the Sugar Beet.¶

The results showed that no difference exists between the superphosphates of either animal or mineral origin.

Estimation of Phosphoric Acid in Slags.

*Formation of Tetrahydrated Ferric Phosphate.***

In eliminating by means of nitric acid the residual hydrochloric acid from slag, which had been treated with the latter reagent to remove silica, a probable source of error is shown by the author in that a tetrahydrated ferric phosphate, $Fe_2(PO_4)_2 + 4H_2O$, is precipitated as a yellow granular powder. This differs from the normal ferric phosphate resulting from the precipitation of a ferric salt by disodium phosphate in not suffering dehydration at 110°.

*Estimation of Phosphoric Acid in the Presence of Silica.**

The author proves by numerous experiments that phosphoric acid may be estimated in the presence of pretty large quantities of silica (solution of soluble glass acidified with hydrochloric acid was employed) when the precipitate of ammonium phosphomolybdate is washed with pure cold water. As the liquid runs through the filter turbid at the end, double filters should be used.

Results of Work Done During the Year.

In answer to a circular letter sent out in the spring, forty-four replies were received, and thirty-seven chemists consented to participate in the work on phosphoric acid. It is to be regretted that many of these have failed to analyze the samples sent them. Early in May three samples were sent to each chemist consenting to do the work, and consisted as follows :

No. 1. A superphosphate.
No. 2. A complete fertilizer.
No. 3. A complete fertilizer containing cotton seed meal and other substances difficult to oxidize.

These samples were prepared with the utmost care, and no pains were spared to insure absolute uniformity in the materials submitted for examination. The fertilizers had probably been made many months when they were collected for this work. They were first air-dried in thin layers for several days, and after grinding were passed through a sieve of forty meshes to the linear inch; the samples then stood for several days more, and were again mixed, first, in large jars, then by passing through a coarser sieve, and finally by hand on heavy paper, after which they were rapidly bottled and sealed.

From the specimens herewith submitted you may judge of the thoroughness of this work. It does not appear probable, therefore, that the differences in the analytical results presented in the following tables can be attributed to any lack of uniformity in the samples, or to any dereliction on the part of your reporter.

These tables reveal discrepancies alike discouraging and inexplicable. It does not appear that we have made any advance since last year. That the methods employed in these determinations are trustworthy when properly executed follows from the fact that in the hands of a few experienced analysts the results are fairly within the limits of the working error. The fault, therefore, must be ascribed to the chemist, and is doubtless due to a lack of thoroughness, to a want of scrupulous attention to minute details in the processes of solution, precipitation, filtration, washing, etc. Thus we see results which seem to be too high through incomplete washing of the precipitate of ammonium magnesium phosphate; total phosphoric acid too low, owing to incomplete oxidation in the process of solution; insoluble phosphoric acid too high or too low because the ammonium citrate solution was too strong or too weak, acid or alkaline, and so on.

Comment in detail upon the analytical data seems unnecessary. A very few words will suffice. In the first place the averages are given for what they are worth, and it is not claimed nor believed that in all cases they correctly represent the percentage of phosphoric acid present in the sample. The results on moisture are noteworthy, and seem to point to some grave oversight in the execution of the official method, if indeed the method was employed in all cases. It would be interesting to know how many of the chemists actually tested the steam closet to see that the temperature approximated 100° C.

With the possible exception of the soluble, the results on phosphoric acid cannot as yet be regarded as satisfactory. So long as experienced analysts differ, in extreme cases, by 0·7 to 0·8 per cent., and from the average of probable truth by 0·3 to 0·4 per cent., it must be admitted that there is room for improvement. Now if we omit from each table three or four of the analyses which seem to be extreme, there still remain a number which differ by the amounts above mentioned. Nor is this discrepancy confined to any one kind of phosphoric acid, but it is in varying degree true of all.

In the opinion of the reporter, the remedy for all this is to be sought not so much in the improvement of the methods of analysis as in the increased care with which the details of the methods are executed after having been once adopted by this association.

Believing that changes in the official methods should be made with the greatest caution, and only for the best of reasons, the following recommendations are suggested after much hesitation :

1. That in the preparation of the solution of water-soluble P_2O_5 the washing be continued until the filtrate measures 300 c. c.
2. That in the *Chemical Bulletin*, No. 24, p. 225, the second line from top of page be changed to read as follows :

Filter the warm solution quickly through a 12½ centimeter plaited filter, wash twice with half-strength ammonium citrate solution, and then with water of ordinary temperature.

3. That in all cases of fertilizers containing cotton seed meal, the solution for total phosphoric acid be prepared by the $Mg(NO_3)_2$ method.
4. That the association advise, in the preparation of the solution of total phosphoric acid, the use of method No. 2 (30 c. c. HNO_3 + HCl) for superphosphates and other samples free from organic matter; and the $Mg(NO_3)_2$ method for all cases in which organic matter is present.

It is further recommended that with these changes the present methods of determining phosphoric acid be continued, subject, of course, to modification by the association.

* These abstracts were prepared by Mr. W. H. Krug, of the Chemical Division, Department of Agriculture.

† Hundeshagen, Fres., *Zeitsch. fur Anal. Chem.*, xxviii., 165-172.

‡ Hughes, J., *Chem. News*, lx., 91.

§ Reitmar, O., *Zeitsch. fur Angew. Chem.*, 1889, 702-9, and 1890, 19-25.

‖ Reitmar, O., *Zeitsch. fur Angew. Chem.*, xc., 196-210.

¶ Stoklasa, J., *Bohm. Zeitsch. fur Zucker-industrie*, xiv., 137-142; *Chem. Centralbl.*, 1890, 1, 771.

** Arth, G., *Bull. Soc. Chem.* (3), ii., 324-327; *Jour. Chem. Soc.*, March, 1890, 282.

* Preis, K., *Listy Chem.*, xiii., 153-154; *Jour. Chem. Soc.*, July, 1888, 825.

† The long tables which follow are omitted as not being necessary for a comprehension of the processes and the arguments based thereon.—Ed. C. N.

ILLUMINATING FLAMES.*

By Professor VIVIAN B. LEWES, F.I.C., F.C.S.

FLAME has always had an attraction for us which has been rivaled by few other natural phenomena; and whether we look back to the times when the old fire worshipers treated it as a deity or take the present century and trace the work which has been done and the discussions which have been held as to its cause, and the actions which render it luminous or destroy its light-giving power, we are fain to admit that a subject which has drawn to it so much attention for upward of twenty centuries must be a worthy object for research, until such time as we have mastered every detail that bears upon the subject. It is upon flame that we have up to the present always depended for artificial illumination; and whether that flame has been derived from the torch, the rushlight, candle, oil lamp or coal gas, is has played a part second to none in our domestic comfort; while with the birth and development of coal gas in the early years of this century flame became an important commercial factor in the history of the country. It was not until the waning years of the last century that Lavoisier's historical researches upon combustion gave us the key to the action which leads to the formation of flame; and since that time its history has teemed with important researches, and still more important applications, which have to-day borne fruit in the improvements we see on every side, in our methods of utilizing flame both for heating and illuminating purposes.

Flame, be it luminous or non-luminous, is produced by the combustion of gaseous matter, and a moment's consideration will render this clear to our mind. Take a piece of Wallsend or silkstone coal and note how it burns on the hearth—first swelling and giving out tarry vapors, which ignite and form jets of flame, and these, encircling the coal, carry on the action, and give us the bright mass of flame which renders our English hearth so cheery a companion. On the other hand, take the coke which is derived from this coal from its destructive distillation in the gas retort, and watch the clear coke fire as it burns. Here you have no flame of the kind given by the coal, but simply the glowing mass of fuel, with, at most, a small blue lambent flame playing over its surface.

What is it that has happened during the conversion of the coal into coke which made so great a difference in its method of combustion? If we analyze the coal and then the coke formed from it, we can at once trace the cause which has given us in the one case flame and in the other none:

	Silkstone Coal.	Coke from Silkstone Coal.
Carbon	79·0	89·0
Hydrogen	5·2	1·0
Nitrogen	1·5	1·0
Sulphur	1·5	1·2
Moisture	4·0	1·2
Ash	2·8	5·2
Oxygen	6·0	1·4
	100·0	100·0

The conversion of the coal into coke has been accompanied by the elimination of hydrogen, which, partly free and partly in combination with carbon, has been driven off, and has formed the coal gas, and with the destruction of the constituents capable of forming gas, the property of burning with flame has disappeared. Again, take a piece of pine wood and ignite it. Its combustion will be marked by a large and luminous flame, while after conversion into charcoal, by eliminating of its gas-producing constituents, it burns with a flameless combustion. From such experiments as these we are forced to the conviction that flame is gas or vapor undergoing combustion; and inasmuch as combustion is chemical combination, we can define flame as being gaseous matter undergoing active chemical combination.

In all the earlier experiments with flame and with the other phenomena of combustion, it was only those substances which ordinarily burnt in air that were studied and experimented with; those bodies which would burn in air being called combustibles, while oxygen and air were looked upon as supporters of combustion. This conventional limitation of the processes of combustion still exists. A little reflection, however, shows us that such terms must be purely relative, as, if flame depends upon active chemical combination taking place between gases, it can only exist where the combining gases are present, and it cannot matter which of them has the credit of being the combustible, as a jet of air or oxygen will burn just as well in an atmosphere of coal gas or hydrogen as the hydrogen or gas would in air.

It might be imagined that, having come to these conclusions with regard to flame, it would be a comparatively simple matter to solve the other problems connected with it, but, on studying the subject, it is at once found that the physical and chemical actions taking place are of the greatest complexity, and are in many cases governed by laws of which we know but little. In the propagation of flame, for instance, the combination of the inflammable constituents at the first moment of combustion gives rise to a great increase in temperature, which in many cases is sufficient to check and alter the combination, and in some instances even to cause dissociation of the products formed in the earlier phases of combustion; so that the combination seems to take place in waves, and not evenly, as one might at first imagine, with the result that the maximum temperature of a flame is never so great as one would expect from calculations based on the heat of combustion of the gases and the specific heat of the products and residual nitrogen from the air. These points, together with the rate of propagation and burning of gases, have been the subject of historical researches by Bunsen, Deville, Berthelot, and others, but much still remains to be done before we arrive at any final conclusion on the subject.

By far the most interesting, and at the same time important, chapter in the history of flame, however, is the consideration of the causes which lead to the luminosity of those flames upon which we depend for most of our domestic lighting; and these offer so beautiful a field for both physical and chemical research, that they have attracted the attention of many observers, and form no inconsiderable addition to the chemical history of this century. In 1816, while engaged upon those celebrated researches which culminated in the discovery of the miner's safety lamp, Sir Humphry Davy noticed certain facts which led him to work out and propound his theory of the causes which led to luminosity in flame—a theory which is generally stated as being that the presence of solid particles in the flame is essential to its luminosity. This theory remained unquestioned until 1868, when Professor E. Frankland, in his celebrated communication to the Royal Society, showed that although incandescent solid matter in a flame renders it luminous, luminosity is also in many cases produced when the flame contains very dense vapors at a sufficiently high temperature, and also that a non-luminous flame may be rendered luminous by increasing the pressure.

This gave rise to a storm of criticism, and the next few years drew forth a rich crop of papers on the subject. Professor Frankland not only showed that flames might be luminous without containing solid particles, but advanced the theory that the luminosity in the flame of a burning gaseous hydrocarbon was due to dense hydrocarbon vapors, and pointed out that the soot deposited upon any cool substance held in such a flame contained hydrogen. To this W. Stein replied, showing that the deposited soot contained less than 1 per cent. of hydrogen, which was, therefore, probably only occluded by the carbon; and also, that if it had been present as a vapor in the flame, it ought, on being heated to the same temperature as the flame, to be once again volatile, which it undoubtedly is not. In 1874 Soret attempted to show that the cause of luminosity in flame really does depend upon the presence of solid particles, by focusing the sun's rays upon a luminous flame, and examining the reflected light by means of a Nicol prism, and rather later Burch pursued the same line of research, but employed the spectroscope for his examination of the reflected light. Their results point unmistakably to the presence of solid particles, and at the present time I think there is very little doubt in any one's mind that, as far as the flames of candles, gas, and oil are concerned, Sir Humphry Davy's theory is the correct one. Indeed, I am strongly of opinion that, although in certain points Davy went a little too far in his theory, had he been still among us we should have found that, in his own mind, he applied his theory more especially to the flames of our ordinary illuminants, as in his original memoir he speaks of "common flames," and distinctly says that "when in flames pure gaseous matter is burned, the light is extremely feeble," and again, "the intensity of the light of flames depends principally upon the production and ignition of solid matter."

While this war of solid particles *versus* dense vapors was raging, Hilgard, Landolt, Blochmann, and Heumann were trying to trace the chemical actions taking place in various flames, and the causes which led to loss of luminosity when air was mixed with coal gas before combustion in the Bunsen burner. Heumann added the further proof to the "solid particle" theory of luminosity that all flames which owe their luminosity to incandescent solid matter give definite shadows, while those in which luminosity is due to dense vapors give none; and that candle, oil, and gas flame all cause well defined shadows.

This brings the work done upon the cause of luminosity down to the present time. The accepted description of a luminous flame now is that it consists of several zones—an inner one, in which no combustion is taking place; a central one, in which, either by selective combustion or by direct decomposition by heat, carbon or very dense hydrocarbons are liberated; and, being heated to incandescence at the moment of production by the combustion of other gases present in the flame, give it luminosity; and an outer one, which consists of the products of combustion and atmospheric air heated to incandescence, and in which combustion is complete.

The work of Soret, Burch, and Heumann proves beyond doubt that our ordinary illuminating flames contain in the luminous zone particles of solid matter; and the only solid which could be present is carbon, either pure or containing the merest trace of hydrogen. The chief question now remaining to be solved, consequently, is the action taking place which leads to the formation of the solid particles in the luminous zone of the flame. During the last two years I have devoted a considerable amount of time and attention to the study of this subject, and I think I have found the key to this important problem—important from a practical point of view, because, until it is thoroughly solved, all efforts to improve our illuminating gases and the burners at which we consume them can only be the outcome of experiments made without a definite idea of the means to employ in order to obtain the results we desire.

Coal gas is a mixture of hydrocarbons with hydrogen and small quantities of carbon monoxide; and it also contains traces of carbon dioxide, nitrogen, and oxygen. The gas manager, however, does his utmost to eliminate the last three; which, if present in anything but the merest traces, would seriously injure the illuminating value of the gas. An analysis of the South Metropolitan Company's gas gives the following as its composition:

Hydrogen	57·08
Hydrocarbons—	
Unsaturated (containing 0·035 per cent. of acetylene)	4·38
Saturated	33·99
Carbon monoxide	2·63
Carbon dioxide	0·79
Nitrogen	0·96
Oxygen	0·15
Bisulphide of carbon	0·02
	100·00

The unsaturated hydrocarbons consist of ethylene, benzene, propylene, butylene, acetylene, and probably also traces of crotonylene and others; while the saturated hydrocarbons consist chiefly of methane, with traces of ethane, propane, and butane.

Analyses made by Landolt of gases withdrawn from various parts of a luminous coal gas flame, and also a long series of analyses which I have made, show that as the gas leaves the burner the hydrogen is the first to be consumed; and that in the passage up the non-luminous part of the flame the carbon monoxide largely increases in quantity, while at the same time the methane rapidly decreases, and the unsaturated hydrocarbons seem the least affected. In the luminous zone the unsaturated hydrocarbons rapidly disappear; while the carbon monoxide formed in the inner zone, and also the residual hydrogen and methane, undergo combustion. Professor Smithells, in a paper read before the Chemical Society in December last, also proved that, during the incomplete combustion taking place in the inner cone of a Bunsen flame, this same increase in the amount of carbon monoxide was to be observed. The fact that the decrease in quantity of the unsaturated hydrocarbons was but slow in the inner zone and then took place with considerable rapidity in the luminous zone favored the theory that they were broken up by heat in that portion of the flame, and liberated the carbon; which, by its incandescence, gave the luminosity. But it does not seem to have occurred to any one to try to determine whether the unsaturated hydrocarbons at the top of the non-luminous zone were of the same description as those in the coal gas.

It is a matter of common observation that the checked combustion of a luminous flame at once gives rise to the escape of acetylene, and also that if a Bunsen burner catches light at the bottom, large quantities of acetylene are formed, of which the presence is at once detected by its distinctive and pungent odor. These facts suggested the idea that in the inner cone of the flame acetylene might be formed by decomposition of the original hydrocarbons; and experiment showed this to be the case.

Of the unsaturated hydrocarbons present in coal gas, 0·8 per cent. consist of acetylene; while at the top of the non-luminous zone of a flat flame produced from the same gas between 80 and 90 per cent. of the unsaturated hydrocarbons present consist of acetylene; and in all the other luminous flames experimented with the same action was found to take place.

On taking the most important hydrocarbons present in the coal gas, mixing them with about 20 per cent. of air, and passing them through a tube heated to the temperature existing near the top of the inner non-luminous zone, the following results were obtained: Methane gave rise to unsaturated hydrocarbons, acetylene, and carbon monoxide; ethylene gave acetylene and carbon monoxide; hydrogen charged with benzene vapor gave the same; and ethane gave unsaturated hydrocarbons, acetylene, and carbon monoxide. These experiments clearly show that in the inner non-luminous zone of the flame, the heat generated by the combustion of the hydrogen of the coal gas in the presence of the small proportion of air drawn into the flame at this point causes the conversion of the hydrocarbons present in the gas into acetylene and carbon monoxide.

Acetylene is a clear, colorless gas, with a strong and disagreeable odor, and consists of 24 parts by weight of carbon combined with 2 parts by weight of hydrogen. It is one of those bodies which, during their formation, take in heat instead of giving it out, and it is, therefore, called an "endothermic" compound. Such substances are especially liable to decomposition, as this is accompanied by a rise in temperature instead of, as is the case with most decompositions, an absorption of heat. Acetylene is decomposed at a bright red heat into carbon and hydrogen, together with traces of tarry matter and ethylene; while Berthelot has shown it to be so unstable that it can be broken up into carbon and hydrogen by detonating a percussion cap in it.

These important points being established, it is necessary to ascertain if the temperature existing in the various parts of a flame give any clew to the actions going on within them. The beautiful platinum and platinum-rhodium thermo-couple devised by M. Le Chatelier, and introduced to us by Mr. W. Chandler Roberts-Austen, gives a means of measuring the temperatures of flames with an ease and comparative accuracy which was never before hoped for. I made a small thermo-couple of platinum and 10 per cent. rhodium-platinum wire, using it as thin as possible to reduce errors from loss of heat by conduction, and keeping the wires of considerable length to prevent any chance of rise of temperature introducing conflicting currents at the connections with the galvanometer wires. A reflecting galvanometer was employed and sufficient resistance introduced into the circuit to keep the spot of light upon the scale at the highest temperatures of the flame; and the scale was then graduated for temperature by taking water at 0° and 100° C., and checking the higher temperature by the fusing points of the chlorides of the alkalies and alkaline earths, as determined by Dr. Carnelly.

With this arrangement I was able to map out the temperatures existing in the flat flame in which I had traced out the changes taking place in the constituents of the gas; and I found that the temperature rapidly rose from 500° C. half an inch above the burner to a little over 1,200° C. at the commencement of the luminous zone—the luminous edges having a temperature of 1,216° C.; and these temperatures were further increased in the luminous zone until near the top of the flame 1,368° C. was reached. This at once gives us the secret of the luminosity. From the mouth of the jet and up to a temperature of 1,000° to 1,200° C., we have the formation of acetylene from the original hydrocarbons; but the moment the requisite temperature is reached by the combustion of the hydrogen and carbon monoxide, the acetylene decomposes, with future rise of temperature, and the carbon heated to incandescence radiates heat and light.

If a luminous flame be cooled its luminosity is at once diminished, and may be destroyed, while as the propagation of flame requires a certain temperature, a further cooling will extinguish it. In the outer edge of a flame, the rapid inrush of air sucked into the flame so lowers the temperature that a thin envelope is rendered non-luminous, the actions checked, and traces of the gas unconsumed allowed to escape unconsumed by the extinction of the extreme limit of the flame, and delicate analysis shows that every luminous flame burning freely in air gives off distinct traces of carbon monoxide, acetylene, and even such highly inflammable gases as methane and hydrogen.

Ever since the structure of flame has been noted and discussed, it has been accepted as a fact beyond dispute that the outer, almost invisible, zone which is interposed between the air and the luminous zone of the

* A lecture delivered at London Institution, February 18, 1892.

flame is the area of complete combustion, and that here the unburned remnants of the flame gases, meeting the air, freely take up oxygen, and are converted into the comparatively harmless products of combustion carbon dioxide and water vapor, which only need partial removal by any haphazard process of ventilation to keep the air of the room fit to support animal life. The facts I have brought before you show that this is not the case, and they fully explain why gas is so oppressive in a badly-ventilated apartment.

It has always been the custom to speak of flames as built up of zones; and, although there are no sharp lines of demarkation, in the actions taking place, which would warrant this, still, three distinct portions are visible to the eye. If we divide the luminous flame into zones it would be, perhaps, best looked at as consisting of three, viz.:

(1) The inner zone, in which the temperature rises from a comparatively low point at the mouth of the burner to about 1,000° C. at the apex of the zone. In this portion of the flame the constituents of the gas undergo various decompositions and interactions which culminate in the conversion of the heavier hydrocarbons into acetylene—carbon monoxide being also produced; and these, with the products of combustion and residual hydrogen, pass into the next phase of action.

(2) The luminous zone, in which the temperature ranges from 1,000° C. up to a little over 1,300° C. Here the acetylene formed in the inner zone becomes decomposed by heat, with liberation of carbon, which at the moment of production is heated to incandescence by the combustion of the carbon monoxide and hydrogen, and gives luminosity to the flame.

(3) The extreme outer cone, in which, combustion being nearly completed, the cooling and diluting influence of the entering air renders a thin layer of the flame non-luminous, and finally extinguishes it. With ordinary coal gas this results in the escape of traces of hydrogen, methane, carbon monoxide and acetylene; while with a very rich gas unconsumed carbon also escapes.

This description of a luminous flame is of necessity far from complete, as it leaves out of consideration the interactions which lead to the formation of acetylene and also the decompositions going on in the various parts of the flame between the products of combustion and the flame gases; but I think it marks a considerable advance in our knowledge of the main actions which lead to luminosity—the other interactions being at best subsidiary to it.

Having obtained a clear idea of the causes which lead to luminosity in flame, we are enabled for the first time to clearly understand the actions taking place in the atmospheric or Bunsen burner, the invention of which revolutionized our methods of heating by gas, and made coal gas one of the most important of our domestic fuels.

When it was first found that the admixture of a certain proportion of air with coal gas before combustion caused it to burn with a non-luminous flame, it was at once accepted, as an explanation of the phenomenon, that the extra oxygen so led into the inner cone of the flame, by causing complete combustion in the central zone, burnt up the carbon before it could be heated to incandescence, and so destroyed its light-giving power. Some years later, however, Knapp and others showed that, by mingling inert diluents, such as nitrogen, carbon dioxide, or even steam, with the gas before combustion, non-luminosity could be produced. It was then recognized that the diluting and cooling action of the nitrogen in air played an important part, and some observers held that it was this, and not the oxygen, which was the cause of non-luminosity.

On measuring the amount of air and of nitrogen respectively able to render a Bunsen flame non-luminous, they are found to be practically the same, while the quantity of oxygen present in the air used, when passed into the gas by itself, still gives a very luminous flame. This certainly looks as if it were the nitrogen that was doing the work. If this were so, the temperature of the flame rendered non-luminous by nitrogen should be the same as that of the flame rendered non-luminous by air, but on testing these the fallacy of such a supposition is at once exposed. This will be seen by the following table:

Part of Flame.	Temperatures existing in a Bunsen Flame rendered Non-luminous by— Nitrogen.	Air.
½ inch above burner	30° C.	54° C.
1½ inch above burner	111° C.	175° C.
Tip of inner cone	444° C.	1090° C.
Center of inner cone	999° C.	1533° C.
Tip of outer cone	1151° C.	1175° C.

These temperatures clearly show that a very considerable amount of combustion is due to the oxygen of the air, and make it perfectly manifest that both the oxygen and the nitrogen are acting in bringing about the loss of luminosity.

While working at these points, I found that if mixtures of nitrogen and oxygen, poorer in oxygen than air, were employed, it was practically only the nitrogen which acted—the diluting effect being so strong that the oxygen was prevented from taking any active part. With air, both act, while with mixtures richer in oxygen than air, the oxygen alone acts—the nitrogen being apparently unable to exercise any retarding influence. The same result is obtained if excess of air is mixed with the gas before combustion. If the quantity of air reaches a point at which the proportion of the oxygen in the air is to the gas as 0·5 : 1, then the diluting influence of the nitrogen is lost, and the appearance of the flame becomes entirely altered. The normal Bunsen flame burns with a lilac-colored inner and blue outer zone; but the moment the quantity of air reaches the ratio mentioned, the flame becomes short and fierce and the inner zone changes to a greenish color—the highest temperature in the flame at the same time increasing nearly 100° C. Experiments show that the nitrogen acts in the normal Bunsen flame by so diluting and protecting the carbons that a far higher temperature is needed for their decomposition; and this action gives time for the oxygen of the air to consume them without liberation of carbon, and hence without luminosity.

In conclusion, I think we may express the actions which lead to loss of luminosity in the normal Bunsen flame in the following way:

(1) The chemical activity of the oxygen introduced in the air, which, by burning up the molecules of hydrocarbons before, in their diluted condition, they undergo decomposition, causes loss of luminosity.

(2) The diluting action of the nitrogen of the air, which, by increasing the temperature necessary to bring about the partial decomposition of the hydrocarbons, prevents formation of acetylene, and in this way will, by itself, cause non-luminosity; and in the normal Bunsen flame it acts by doing this until destruction of the hydrocarbons by oxidation has taken place.

(3) The cooling influence of the air introduced, which is able to add to the general result, although the cooling is less than the increase in temperature brought about by the oxidation due to the oxygen in the air.

THE GENERAL CIRCULATION OF THE ATMOSPHERE.*

IF the question of the general circulation of the atmosphere were referred to a meeting of educated people, one might be sure that ninety out of a hundred who could give any answer at all would explain it by the time-honored equatorial and polar current; if any one initiated in the subject sat near, one would observe a pitying smile upon his lips, and if asked for his opinion, he would relegate that current of sacred memory to the region of the fables, or at most only allow it to hold sway, with certain limitations, in the tropical and subtropical zones, the region of the trade winds; the temperate and cold zones, however, would be reserved for the dominion of the variable winds and of newly arisen cyclones and anticyclones, of which we cannot tell whence they come and whither they go, *i. e.*, for the origin and disappearance of which we cannot lay down any laws. And if there were several of these initiated persons present, a discussion would at once occur, from which no one could obtain a clear idea, and which would leave every one with the impression that nothing certain was known about the subject. I suppose that you have been present at such a discussion, and have appealed to me to explain to you the present state of our knowledge of this subject.

I undertake this task the more willingly, since the question of the general circulation of the atmosphere has but recently entered upon a new stage, which marks a great step toward the complete solution of the question, and because it is very desirable to obtain as wide a diffusion as possible for this theory, which corresponds to the present state of the science.

In this question especially, as in many others, the history of the developement is exceedingly instructive, and of the greatest value in aiding a comprehension of the subject. I propose, therefore, that you should follow me through the different stages which the explanation of the general circulation of the atmosphere has undergone. Little or nothing more will then be wanting in order to understand the answer to the question at issue.

Dove was the first person who advanced a theory of the general circulation of the atmosphere after meteorology took a place among the exact sciences. He considered the question from a high and correct standpoint, because he considered the atmospheric envelope of the earth as a whole, which received its motion from the sun, the universal motor. According to his theory, the explanation of the general circulation of the atmosphere took the following form:

The heat of the sun is not uniformly distributed over the earth's surface, but decreases from the equator to the poles. The greatest heat occurs at the equator and the least at the poles. The air which is greatly heated at the equator must consequently rise, an ascending current must be developed there (the celebrated *courant ascendant*). The zone of calms is the region of the ascending air current. The air carried upward must flow away above toward the poles, while, owing to the rotation of the earth, it endeavors to deviate to the right; the equatorial current is originated as an upper southwest wind, in the higher strata of the atmosphere. The flow of the upper air toward the poles is compensated below by the flow of the air toward the equator, and this polar current seems to be turned away toward the west, owing to the rotation of the earth; it appears on the earth's surface as a northwest wind, and blows as far as the zone of calms, where it ceases, and the air brought with it is carried upward in the ascending air current, where the circulation then begins afresh.

You see that this theory leads to a circulation of the air between pole and equator. The air rises at the equator and flows toward the poles, in order to descend there and to flow again toward the equator. But Dove states expressly that the equatorial current partially descends, even in the temperate latitudes, down to the bed of the polar current. If this happens, and according to Dove this continually occurs, then both winds, the equatorial and polar currents, begin the conflict for the mastery. The variable winds of the temperate zone arise out of this conflict, and Dove deduced therefrom his law of wind gyration. The description which he gave of this conflict of the opposing equatorial and polar currents is a thoroughly masterly picture, and it is in a great measure owing to this elaborate completion of his exposition that his theory of the general circulation of the atmosphere and his law of wind gyration were accepted by scientific men. The reader is carried away by it as if he were present at the conflict of the winds in Æolus' mythological cave, and he is inclined to believe that science verifies the ancient mythology so far as regards the lower latitudes. Dove's theory found an actual support in the trade winds, and in the law of wind gyration which generally obtains in Central Europe. In fact, in our regions, the wind rotates very frequently from east through south to west and north. Dove's explanation of this, the conflict of the equatorial and polar currents, must have appeared to be correct as long as no more serious investigations existed.

Since 1863, weather telegraphy and synoptic weather charts have led to the discovery of the baric wind law (Buys Ballot's law), and the position was at once changed. We learned that the winds depend upon the differences of pressure which prevail over the region under consideration, and that they circulate round the place of lowest pressure; *i. e.*, with us, they flow to the place of lowest pressure, in spirals opposite to the movement of watch hands.

It was now said that the cause of the winds in our latitudes was not the great heating of the air at the equator, but the differences of pressure which were formed in the temperate zone. The law of wind gyration also became untenable. It was found that the swirls which arose about the place of lowest pressure do not stand still, but move, and it was seen that Dove's law of wind gyration for places which lie northward of the tracks of these swirls does not hold good; in fact, that the rotation is exactly the reverse.

The reason why Dove's law of wind gyration mostly holds good in Germany and Central Europe was found to be that the tracks of the swirls almost always lie to the northward of Central Europe, and therefore the law must hold good there. But as often as a swirl moves more southward, all places in Central Europe which lie to the north of it have a wind rotation which is opposed to Dove's law.

The equatorial and polar currents, so far as regards the higher latitudes, were thus driven off the field, and the conflict between them, so beautifully described, was again relegated to the mythical cave of Æolus. As it was feared that the wheat might be thrown away with the chaff, it was wished that the equatorial and polar current should be banished from the higher latitudes altogether, but left, in a more limited sense, only in the regions of the trade winds—between the zone of calms and about 30° north and south latitude; for here it was clear that Dove's theory held good. People unceremoniously denied the right of the polar current to blow beyond the 35th parallel, for in this latitude, as observations show, a band of high pressure encircles the whole earth, while from there the pressure decreases both toward the equator and the poles. But according to the baric wind law the wind can only flow from a place of higher to one of lower pressure; the air can therefore only flow from the 35th parallel toward the pole, and not the reverse. The polar current was thereby banished without mercy from the higher latitudes. The equatorial current fared somewhat better in the upper regions. Many persons allowed it to remain in a small degree, especially those who recognized the accuracy of the calculation according to which in the higher atmosphere, about 4,000 m. and over, the pressure decreases from the equator to the pole. But very few persons knew what to make of this equatorial current in the upper regions, and so at all events it was little regarded. Generally speaking, the *regime* of cyclones and anticyclones was established for the higher latitudes, and people were completely absorbed in investigating the details of their qualities and tracks, without having hitherto succeeded in obtaining a satisfactory explanation of their origin and development. With regard to the propagation of cyclones, it was observed that with few exceptions they advanced from the westward to the eastward. Gradually, opinions became general that it was the southwest and west wind of the upper regions which brought the cyclones with it; some persons explained this west wind in the upper regions as the equatorial current. But, on the whole, the general opinion of this period favored the rejection of Dove's polar and equatorial current, and the explanation of all winds by the prevalent differences of pressure, without being able to account for the origin of the latter.

Dove was of an excitable temperament, and he strongly combated these new views, and laid too much weight on the defense of the defective portion of his theory. His contest was fruitless, and only caused him to be accused with some justice of hindering the progress of meteorology by his great authority. Dove at length remained silent, and the funeral anthem of the polar and equatorial current was then chanted.

Muhry, a well-known meteorologist of the Dove school, survived him, and constantly raised his voice in favor of Dove's equatorial and polar current; he attentively followed the progress of meteorology until his death, a few years ago, and the way in which he frequently warned meteorologists against entirely excluding the equatorial and polar current from their considerations is quite stirring. He was continually trying to turn attention to it, but with him disappeared the last defender of Dove's theory.

But while meteorologists were almost exclusively concerned with the details of the phenomena offered by cyclones and anti-cyclones, and almost lost sight of the great problems which the consideration of the general circulation of the atmosphere affords, a revolution was being prepared, at first only individually, but gradually more generally, which disposed minds to the more favorable consideration of the general movements of the atmosphere.

More than thirty years ago, Ferrel, the great American meteorologist, was occupied with the question of the general circulation of the atmosphere. He developed its laws in a mathematical form, and arrived at the following theory:

Three great zones of calms exist round the earth, one at the equator (or near it), usually called the calm belt, the second and third 35° north and south of the equator, the so-called "horse latitudes." Between the calm belt and the horse latitudes, the northeast or southeast trade wind prevails at the surface of the earth, and in the higher regions above them the anti-trade (southwest or northwest). In the calm belt, in which no other than an ascending movement of the air exists up to the greatest heights, an upheaval of air occurs, and in latitude 35° a descent of the same. Northward of 35° N. and southward of 35° S., southwest and west winds prevail both at the earth's surface and at great altitudes, while at a mean height a return northwesterly current prevails. The heat of the sun, or difference of temperature between equator and pole, is the cause of this general circulation of the atmosphere, as Dove maintained; the deviation of the wind from the direction of the meridians arises from the rotation of the earth.

This whole theory of the circulation of the atmosphere, which Ferrel deduced by mathematical means, differs considerably from Dove's, but shows that Dove's fundamental idea was sound and worthy of respect.

Ferrel's investigation certainly remained long unknown in Europe, and when at length it became known, it was only received with a purely theoretical interest. It seemed to have no connection with the present almost exclusively interesting question of the origin, development and propagation of cyclones, and

* Translation of a lecture delivered by Dr. J. M. Pernter before the Scientific Club in Vienna.—*Nature.*

so it was in fact set aside; although from that time people frequently referred to it, and began to pay more attention to the currents of the general circulation. But it was only in 1885 that Sprung, in his treatise on meteorology, could write: "And so the conviction is now often expressed that we have gone too far in accrediting the individual systems (cyclones and anticyclones) with the sole control over the motions of the air in higher latitudes;" and he then sets up a system of general circulation, based on the same principles as those of Ferrel. Sprung's system corresponds tolerably well with Ferrel's, but he also finds in the trade wind zone that the wind direction at a mean height deviates from the direction of the trade, namely, southeast, over the northeast trade wind. At great heights the westerly winds prevail from the equator to the pole, without passing to calms in the horse latitudes. At the equator there exists an actual conical calm zone pointing upward, in which only ascending air currents prevail up to the highest altitudes.

Although, owing to the esteem which Sprung's treatise everywhere found, this theory of the general circulation of the atmosphere continued to spread, it did not arouse great interest, because it did not take special account of the influence of these general currents on the formation and propagation of cyclones, which justly continued to attract the most general attention.

This influence of the general atmospheric circulation was first insisted upon by the celebrated physicist and mechanician, Werner Siemens, in 1886. He considered the origin of the general circulation of the atmosphere from the great and fruitful principle of the conservation of energy.

Siemens introduced his far-seeing considerations with the remark that, even if Dove's theory of the general circulation of the atmosphere, which consisted of the ascending air current at the equator and the development therefrom of the equatorial and polar current, with its conflicts for mastery in the temperate zones, were defective, yet this explanation was at all events more satisfactory than the "present almost exclusive reference of the motions of the air in higher latitudes to minima and maxima of pressure." He rightly asks that the seat of the forces—which accumulate, in a manner that is not at present evident, powerful energy in cyclones and anticyclones, which produce storms and whirlwinds—and the point of their attack may be indicated. Siemens makes no new assertion when he attributes all the energy which occurs in cyclones and anticyclones to the heat of the sun, but he discusses in a new and very noteworthy manner the way in which the sun's heat produces the storms of our latitudes.

Siemens explains the general circulation of the atmosphere according to the following principles: (1) Without the heat of the sun the earth's atmosphere would be in a state of relative repose, *i. e.*, it would everywhere rotate with the angular velocity of the earth's rotation; we should have no winds. (2) In reality the earth and its atmosphere are unequally heated, most at the equator and least at the poles; consequently, air currents must arise from the equator toward the poles. (3) The energy which is accumulated by the rotation of the atmosphere about the earth's axis must, however, remain constant and unchanged; the theory of the conservation of energy requires this. If, therefore, a continual change of the geographical position of masses of air takes place through equatorial and polar air currents, it must take place so that the velocity of rotation of the whole atmosphere remains unchanged. This is only the case when the velocity of rotation of the whole atmosphere over lower latitudes lags behind that of the earth, but in higher latitudes outstrips it.

It is evident from this that anywhere in middle latitudes, both north and south, there must be a belt round the earth where neither a retardation nor an acceleration occurs, *i. e.*, where the air is in relative repose with regard to the earth. Siemens calculates the position of this belt to be at latitude 35°.

According to Siemens, therefore, we have the following system of air circulation:

Between latitude 35° N. and 35° S., the general movement of the atmosphere is directed toward the west, *i. e.*, east winds constantly prevail there in all latitudes and at all heights. In the vicinity of the equator, where northeast and southeast trades meet, an interference occurs at the *surface of the earth*, which produces the calm zone, but it does not reach to any considerable height. In the higher regions above the calm zone an east wind must likewise prevail.

In the higher latitudes, therefore, northward and westward of the 35th parallels, the general movement of the atmosphere must be directed toward the eastward, and west winds must generally prevail in these latitudes.

Now, what do direct observations say to this system of the general circulation of the atmosphere?

There is no doubt that between the 35th parallels an easterly air current prevails, viz., the trade winds. It is also known that west winds prevail in the higher latitudes, and in the southern hemisphere they blow almost uninterruptedly. But Siemens' theory is not to be considered as proved by these general facts, although they are fully borne out in Ferrel's and Sprung's explanations; we must examine what is new in it more closely. Siemens' exposition requires an easterly air current at the equator, and even in the upper regions above the calm zone. Does this exist? Until a short time ago, it was undoubtedly the general opinion of meteorologists that the calm belt was a zone of actual calms up to the highest altitudes, and that only the slowly ascending current prevailed there; in the vicinity of the calm zone, the trade wind blowing below ought to rise, and with increasing height gradually asssume a poleward direction, to appear soon as an upper southwest trade wind. This theory, which had become rooted by custom and time, was upset by Siemens. Between the 35th parallels there are only easterly currents—the strongest and most purely easterly over the calm belt, and decreasing continually toward latitude 35°; in the upper regions, on approaching latitude 35°, these currents come continually more from the south, and at the earth's surface more from the north. This was then a serious revolution in the theory of the general circulation of the atmosphere, which even the great authority of Siemens could not carry through without further experimental proofs. He had not reduced his investigations to a mathematical form, and so his theory, notwithstanding the great respect due to his name, would with difficulty have obtained greater success, if facts had not recently become known which appeared to confirm it.

It is known that after the Krakatoa eruption in the year 1883, the opinion was expressed that the frequent colored phenomena of the sun in the tropics and the long evening glows were regarded as consequences of this eruption. The spread of these phenomena in the first ten days after the eruption were such that we were obliged to assume that the dust haze thrown out had traveled round the earth in about twelve days from east to west; for the explanation of the diffusion of these phenomena, a violent easterly wind was required in the upper regions of the atmosphere in the vicinity of the equator. For a long time it was this easterly wind which threw doubt upon the whole hypothesis of the unusual appearances which were referred to the Krakatoa eruption. But Siemens' theory of the general circulation of the atmosphere was thereby confirmed. It appeared, however, as if here two hypothesis happened to mutually support each other, and it was a long time before on the one hand the Krakatoa hypothesis, and on the other Siemens' theory, were regarded as established.

This theory found, however, further support—on one hand, in the observations of the motion of high clouds by Abercromby and on the other in the mathematical establishment of Siemens' statement by Oberbeck.

In 1885, Abercromby, during a voyage from Aden to Australia, had observed that in the neighborhood of the equator the cirrus moved from the east. He was much surprised at this, and wrote: "The discovery of an easterly current over the northwest monsoon is not only altogether new, but also quite anomalous." He thought this so important that he undertook another voyage from Mauritius to Bombay, in order to clear up the matter. The result of his further observations is couched in the following terms: "I may point out another very important result of these observations, namely, that the highest air current between the equator and the doldrums is always from some point near east." *

Here, then, was another actual confirmation of Siemens' theory. Two facts—the diffusion of the Krakatoa dust and Abercromby's observations—supported Siemens' theory of air circulation, yet doubts were not quite removed. Voices were loud against the Krakatoa hypothesis and against Abercromby's observations, which allowed another explanation to appear possible. Meteorologists delayed mostly to accept Siemens' theory, because a theoretical, mathematical establishment of it was still lacking. But this was given, as before observed, by Oberbeck, a year or so ago. He arrived at formulæ by which Siemens' theory could be reproduced.

Now, in fact, nothing more was wanting. Siemens' system was confirmed on all sides, by facts and by mathematical treatment. The chief merit for this is certainly due to Oberbeck. Before I bring to your notice the system of the general circulation of the atmosphere, such as is given by the present state of research, I must allude to one other point in Siemens' exposition, namely, the influence which the general circulation of the atmosphere should have on the origin of cyclones and anti-cyclones in our latitudes.

The origin of the maxima ought to be due to the fact that the air flowing from lower to higher latitudes is checked in consequence of the convergence of meridians, and so produces an increase of pressure. Thus we get the maxima, or anti-cyclones. If, then, in consequence of this increase of pressure below, air flows out laterally, and, in consequence of the interference, the confined current turns more to the eastward, it must carry the lower strata with it, and give rise to a rarefaction, causing a minimum, or cyclone. But this is carried away as a whole by the general current, and thus the progression of cyclones is also explained.

Siemens holds very strongly to this explanation, principally because it contains a force which explains the energy which is accumulated in anti-cyclones and cyclones, and which refers finally to the heat of the sun, that maintains the general circulation. But I fear he has overshot the mark here. The meridians converge in the southern hemisphere the same as in the northern. Why, then, do almost constant west winds prevail there below without interference of currents, while with us an almost uninterrupted system of driving cyclones and anti-cyclones exists? Does not this prove that in the formation of cyclones and anti-cyclones another factor is at work, and might not this, perhaps, depend on the peculiar distribution of land and water in the northern hemisphere? Upon this point Siemens will have to modify his views.

From my analysis we can easily sketch the outline of the general circulation of the atmosphere which corresponds to the present state of the science.

In consequence of the unequal heating of the sun and of the rotation of the earth, air currents occur at all parts of the globe. These currents are easterly between 35° N. and 35° S. latitude, and westerly outside this zone.

In the former zone the easterly currents on the earth's surface (in the northern hemisphere) are more northeasterly and northerly the nearer we approach latitude 35°, while in the higher strata they constantly become more southerly as we approach latitude 35°. This explains the circulation between the equator and latitude 35°. *An upper southwest trade wind entirely fails in this region.* † At or near the equator a calm zone must be formed *at the earth's surface*, where the meridional components of the northeast and southeast trades ascend, but the height of the calm zone cannot be considerable. Exactly over the calm zone a pure east wind, and the strongest of the whole zone, will blow, and the higher the strata under consideration, the stronger it will be.

In latitude 35° N. and S., calms exist at the earth's surface. The air, which has an ascending motion in the equatorial calm, has here a descending movement. But above, the current directed poleward continues to exist. Outside this great region, to the north and south, west winds will prevail; while above, the southwest (or the northwest) trade wind blows, which in higher latitudes will become more and more westerly. At the earth's surface, air in southwesterly or northwesterly motion flows from the zone of high pressure at latitude 35°, which becomes more westerly with increasing latitude. At a mean altitude, however, air flows again from the poles toward latitude 35° as a northwest wind.

This is the picture of the general circulation of the atmosphere according to the latest researches. There is undoubtedly much to be completed, and it presents many dark points which remain to be cleared up, but on the whole it possesses every guarantee of truth and reality, and will doubtless soon be generally accepted. The question of the effect upon cyclones and anticyclones of this general circulation of the atmosphere will certainly come to the front, but we shall have to wait for a considerable time for a satisfactory solution of the problem.

* Mr. Abercromby afterward modified this opinion (*Nature*, vol. xxxix., p. 437).—*Translator.*

† This statement as to the failure of the upper southwest trade wind between the equator and latitude 35° was afterward modified (see *Das Wetter*, 1890, p. 158.)—*Translator.*

CAVE DWELLERS IN AFRICA.

WHEN Capt. Grant was descending the Nile, after Speke and he had surveyed the great Victoria Nyanza, he met some native travelers who said to him:

"The most remarkable country in Africa is way down in Katanga. It is the place where copper comes from, and there are great caves in the hills, so high that if we were riding through them on these camels we could not touch the roof with our spears; and people live in them. One of these caves is 400 yards wide, and it took us from sunrise till noon to march through it, and we came out of the hill on the other side."

It was thirty years ago that Capt. Grant heard this remarkable story. It is a curious coincidence that during the very week of his death, last month, there came to Brussels the preliminary report of Lieut. Le Marinel announcing that he had visited the caves of Katanga and seen the people who inhabit them. He approached these hills, which rise about 5,000 ft. above the sea, from the northwest. Another explorer, Mr. Arnot, has visited them from the south, and both sides of these little mountain ranges are found to be dotted with the mouths of caverns, the dark homes of some thousands of people.

Le Marinel says these troglodytes are known as the Bena-Kambabo. Many of their caves are not inhabited, but are simply places of refuge. The openings are so carefully hidden among the rocks or in the underbrush that it is hardly possible to find them; but scores of inhabited caves are scattered like rabbit warrens along the flanks of the hills and can be seen from a distance.

The people have been a thorn in the flesh of King Msiri, one of the most powerful native rulers in Africa. The troglodytes alone among his subjects have for years defied his tax gatherers. The King's army several times marched against them in vain. When their hills were invaded the people simply retreated into the bowels of the earth. Interior passages connect their caves, and they can come to light again far from the place where they vanished into the blackness of their underground homes.

Le Marinel says, however, that Msiri has at last thoroughly cowed his rebellious subjects. They pay him tribute now, though there is little for the tax gatherer to collect, because the King left them hardly a goat when he conquered them.

The hills of Katanga, where these cave dwellers live, are among the loftiest and coldest parts of tropical Africa. Water sometimes freezes in the night. Le Marinel says the Bena-Kambabo are the most ferocious savages he ever met. They are afraid the secrets of their grottoes will be fathomed, and the explorer was not permitted to enter them. Arnot had the same experience on the south side of the hills. He lingered in the neighborhood for days, fed the multitude on hippopotami and antelope and won their friendship, but no bribe tempted them to admit him to their subterranean retreats. He was permitted only to peer in at the openings, where the walls had the appearance of pumice stone. No one knows how large they are.

Arnot says, however, that one of the caves has two mouths, the distance between the openings being five miles. Water flows from many of the openings. There is little doubt that they are natural caves, produced by erosion, and some of them, perhaps, artificially enlarged and connected. Scattered all over this rugged region live these natives, in the largest caves used as the abode of man, herding flocks in their retreats, tilling millet fields in the valleys below. They are always alert to detect danger, when, as a rule, they vanish from view, the earth swallowing them up beyond the ken of their foes.

Turning to the northern part we find two centers of troglodytic habitations, not far from the Mediterranean coast. It seems strange that within a short distance of the sea there are regions still unexplored.

It may be that the cave dwellers which Capt. Lyons said he found four days' march southwest of Tripoli in 1821 no longer exist. At any rate nothing has been written of them for many years. But a little further west, in Tunis, only forty miles from the sea, French soldiers discovered two years ago the largest villages of cave dwellers known in modern times. They have since been visited by several explorers, including Mr. Hamy, the anthropologist. The people are called the Matmatmas, and their two villages, in parallel valleys, contain about 4,000 people.

You might enter one of these valleys and not know until you were right upon the caves that a human being lived there, a part of the populace being off over the hills with their herds and the rest busied under ground with their pottery making and house duties. The caves are excavated in the limestone hills. Dwellings, stables, workshops, everything is under ground. The bare limestone walls of these subterranean rooms are marked with deep scratches, made by the pickaxes that dug them out.

Near the ceiling shelves are excavated on which provisions are stored. They descend to the entrance by a short ladder in an almost perpendicular shaft, upon which fronts the doorway, the only source of light and ventilation. They inter their dead in shallow trenches, almost on the surface. It is a strange spectacle—the

dead occupying the place usually devoted to the living, while the living bury themselves in veritable sepulchers.

These cave dwellers are a contented people. Their homes are warmer in winter and cooler in summer than those of their neighbors. Their villages are hives of industry, and although their manner of life is a recent revelation, not a few articles of European origin have been found in their underground homes.

The great explorer Nachtigal introduced us in 1869 to the troglodytes of the Sahara Desert. They were known only by name before Nachtigal, on his perilous journey, found them among their mountains of Tibesti. A remarkable race are these Tibbus, "the People of the Rocks." Their women are unequaled for beauty among the North African races. None of the diseases that have scourged their northern neighbors is known among them.

It is a land of volcanic rock, of hot springs and geysers, and the natives say the sulphur they collect is their only riches. Several thousands of them live among these mountains in natural caves or between blocks of stones, under roofs of palms or acacia branches. The flesh and milk of goats are almost their sole food. They lead, however, anything but an idyllic existence. Their life is that of the fox surrounded by hunters. On three sides of them live inveterate enemies who covet their women and camels. They are the bravest of fighters, and can hold their own, but they wage war on all the world, and the white race is in the category of their enemies. The result is that we know very little of their country. Nachtigal visited only its northern part.

Their mountains are supposed to run north and south about 300 miles, but the breadth of these ranges is not known. On the east no enemy affronts them; for, looking toward Mecca, they can see only the yellow sands of the Libyan Desert, the most forbidding and terrible waste in the world.

One of the most remarkable stories that Joseph Thomson had to tell when he came home from his trip through Masailand was of the great Mount Elgon, not far from the northeast corner of Victoria Nyanza, and its artificial caves, extraordinary in number and vast in extent.

These caves, he said, were cut out of very compact volcanic agglomerate near the base of the mountain, and they were occupied by whole villages, with their cattle. They were so big that hundreds of people and large herds could live in them. Thomson believed that they were mines in some past age. The works were evidently too vast to be achieved by the simple savages who now inhabit them, and Thomson wondered what superior race could formerly have occupied this region.

Thomson's impressions of these caves were somewhat modified by the studies of Messrs. Jackson and Gadge in 1889, six years after Thomson's visit. They found inhabited caves at an elevation of 7,500 ft. One of them contained thirty large huts. There were other cave villages further down the mountain as well as at its base.

The later explorers believe that these are natural caves. They saw nothing to suggest that they could possibly be the work of man. They found evidence also that years ago the natives lived on the plain in ordinary villages, using the caves at times as a place of refuge from their enemies, until finally they made them their permanent abode. A remarkable mountain is Elgon, its top, even under the tropical sun, nearly reaching the snow line, and its green sides indented with deep pockets—the homes of hundreds of human beings.

Scattered over the western part of the Kalahira Desert in South Africa are the famous Bushmen, who welcome the discovery of a spacious cave as one of the greatest of earthly blessings. Very few of them live in huts; caverns are the home they prefer; and when in their wanderings they fail to find caves, they enlarge holes dug by animals, into which they crawl.

They live so far from the equator that they regard it as a luxury to go to sleep upon the warm ashes from the fire that has cooked their evening meal. These miserable little people may well compete with some of the native Australians for the distinction of being at the bottom of the scale of humanity. The translation of the name of Boers applied to them means "inferior beings."

These are all the cave dwellers as yet known in Africa. It is noteworthy that, with the exception of the Mount Elgon natives, they are believed to be the aborigines of the regions they inhabit. The people in the big cave villages near the Mediterranean are of nearly pure Berber stock; the Tibbus are Berber with some admixture of negro blood; the Katanga cave dwellers were certainly earlier possessors of the land they inhabit than the people who now lord it over them; and the Bushmen are closely allied to the dwarf tribes of the equatorial regions who anthropologists believe were in possession long before the people with whom they now live entered the country. There is little doubt that the northern troglodytes are among the descendants of the cave dwellers of whom Herodotus wrote.—*Mineralogists' Monthly.*

ARCHÆOLOGICAL DISCOVERY IN EGYPT.

THE Cairo correspondent of the London *Times* writes under date May 29: "About two miles east of Alexandria is the plain of Eleusis, now a salt marsh and shallow lake, the result of subsidence of the soil, which at some remote period is believed to have occurred over a large area in the neighborhood of Alexandria. In old times there stood on this plain a temple to Ceres Proserpine, in front of which were placed, as described by ancient writers, colossal statues of Mark Antony and Cleopatra, the former represented as the god Osiris and the latter as the goddess Isis. These statues are described by Mahmoud Falaky, an Egyptian astronomer and savant, in his book, published twenty years ago, on 'Ancient Alexandria.' He had seen them ten years previously when making researches to find the Canopic road and to get material to be used by the late Emperor Napoleon in his 'Vie de Cesar.' Since that time they had disappeared, probably covered over again during the leveling of the ground for cultivation. Daninos Pasha, an energetic local archæologist, lately began excavations, and at a spot strewn with large numbers of granite blocks and columns found, as he believes, the remains of the temple. Close by he dug out a much-mutilated colossal statue in gray granite, representing the head and torso of a woman wearing the insignia and coiffure of Isis. The nose is mutilated, but the prominent eyes, the contour of the cheek, and the firm rounded chin show the characteristic traits of the Ptolemies. The head alone is more than a meter high. The sculpture is of high order and finish, probably the work of an able Greek artist. A large detached fragment represents a portion of a man's right hand, the thumb grasping the fingers of a female hand, which are of proportions corresponding to those of the statue. Daninos Pasha identifies his find as certainly the statue of Cleopatra, and considers it to be probably a portrait statue of the famous queen. If so, it is unique and of very great interest. He is continuing the search for the companion statue of Mark Antony, which is believed to have been removed to a considerable distance, thrown into a hole and covered up. If the search should be successful, these two statues will be among the most valuable and interesting relics of ancient Alexandria."

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TABLE OF CONTENTS.

PAGE

I. ANTHROPOLOGY.—Cave Dwellers in Africa.—Modern troglodytes of Africa recently visited.—A verification of a rumor of many years' standing..... 13781

II. ARCHÆOLOGY.—Archæological Discovery in Egypt.—Recent archæological finds in Egypt.—Probable colossal statues of Mark Antony and Cleopatra..... 13782

III. BACTERIOLOGY.—Micro-Organisms in their Relation to Chemical Change.—By Prof. PERCY F. FRANKLAND.—A recent lecture by this great authority on bacteria, giving the last results obtained in this field by scientists and the wonderful revelations of the work of microbes..... 13776

IV. BIOGRAPHY.—Professor James Thomson.—A great philosopher of Ireland recently deceased.—Note of his life work and physics.—His invention of the inward-flow vortex turbine..... 13776

V. CHEMISTRY.—Illuminating Flames.—By Prof. VIVIAN B. LEWES.—A most interesting lecture on the chemistry and physics of gas flames, suggestive of interesting experimental work..... 13779

Report on Phosphoric Acid.—By W. R. BURNEY.—Methods of determining phosphoric acid and results of work done by the American chemists during the past year, from the proceedings of the Seventh Annual Convention of the Association of Official Agricultural Chemists, at Washington..... 13778

VI. CIVIL ENGINEERING.—Blowing up a Bridge.—An episode of the operations of widening a railroad in England.—1 illustration.. 13773

Note on Farm Railways..... 13778

VII. ELECTRICITY.—Trouvé's Portable Luminous Fountains.—A luminous fountain lighted by the incandescent light current.—1 illustration..... 13769

The Technical Education of the Electrical Engineer.—By Prof. DUGALD C. JACKSON.—What the electrical student should devote his college hours to.—How electrical engineers are made..... 13780

VIII. MECHANICS.—Impact, or the Force of Percussion.—By G. D. HISCOX.—The Much-debated question of the force of the hammer blow practically and mathematically discussed.—The water ram in pipes.—The impact of shot..... 13772

IX. MEDICINE AND HYGIENE.—Immunity against Pneumonia.—A suggestion for inoculation to prevent pneumonia..... 13771

X. METEOROLOGY.—The General Circulation of the Atmosphere.—The laws of storms and of wind currents.—An important review of modern theories and atmospheric operations..... 13780

XI. ENGINEERING.—H. M. S. Ramillies and Repulse.—Two men-of-war to be probably the most powerful battle ships in the world.—Dimensions and general features.—1 illustration..... 13774

Life-Saving Devices.—Continuation of the exhaustive article on the saving of life from wrecks.—5 illustrations..... 13774

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